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Volume I

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The report gives results of a study of the derivation of Multimedia Environmental Goals (MEG's). MEG's are levels of significant contaminants or degradents (in ambient air, water, or land, or in emissions or effluents conveyed to the ambient media) that are judged to be: appropriate for preventing certain negative effects in the surrounding populations or ecosystems; or representative of the control limits achievable through technology. In the context of deriving MEG's, Volume I: offers perspective on the broad range of contaminants whose control is vital to both industry and the public; further develops and defines indicators designating contaminants which must be given priority consideration for immediate control and for subsequent research; brings existing and emerging data together for use in environmental assessment; and explores some basic methodologies which provide the present MEG's, and which also suggest directions for refined methodologies. MEG's are projected for more than 650 pollutants: of these, 216 receive full attention in Volume II.

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MULTIMEDIA ENVIRONMENTAL GOALS FOR ENVIRONMENTAL ASSESSMENT

Volume I

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ABSTRACT

Multimedia Environmental Goals (MEG's) are levels of significant contaminants or degradents (in ambient air, water, or land or in emissions or effluents conveyed to the ambient media) that are judged to be (1) appropriate for preventing certain negative effects in the surrounding populations or ecosystems, or (2) representative of the control limits achievable through technology. MEG's are projected for more than 650 pollutants. Of the projected 650 candidates, 216 receive full attention in Volume II of this report.

In the context of deriving MEG's, this volume attempts (1) to offer perspective on the broad range of contaminants whose control is of vital interest to both industry and the public; (2) to further develop and define indicators designating which contaminants must be given priority consideration for immediate control and for subsequent research; (3) to bring existing and emerging data together in a format efficient for use in environmental assessment; and (4) to explore some basic methodologies which provide the present goals, and which also suggest directions for refined methodologies.

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ABBREVIATIONS AND SYMBOLS

Å	Angstrom unit
ACGIH	American Conference of Governmental Industrial Hygienists
AEC	Atomic Energy Commission
Ag	Silver
Al	Aluminum
As	Arsenic
Au	Gold
B	Boron
Ba	Barium
BAP	Benzo(a)pyrene
B(a)P	Benzo(a)pyrene
BAT	Best Available Technology
Be	Beryllium
B(e)P	Benzo(e)pyrene
Bi	Bismuth
BOD	Biological Oxygen Demand
bp	boiling point
BPT	Best Practicable Technology
Br	Bromine
C	Carbon
°C	Degrees Centigrade
Ca	Calcium
cal	calorie
cc	cubic centimeter
Cd	Cadmium
Ce	Cerium
CFR	Code of Federal Regulations
CIIT	Chemical Industry Institute of Toxicology
Cl	Chlorine

ABBREVIATIONS AND SYMBOLS (cont.)

cm	centimeter
cm^3	cubic centimeter
Co	Cobalt
COD	Chemical Oxygen Demand
Cr	Chromium
Cs	Cesium
Cu	Copper
d	density
DNA	Deoxyribonucleic Acid
dscf	dry standard cubic foot
dscm	dry standard cubic meter
Dy	Dysprosium
EPA	Environmental Protection Agency
EPC	Estimated Permissible Concentration
F	Fluorine
Fe	Iron
Fr	Federal Register
g	gram
Ga	Gallium
Ge	Germanium
H	Hydrogen
ha	hectare
HC	Hydrocarbons
Hf	Hafnium
Hg	Mercury
hr	hour

ABBREVIATIONS AND SYMBOLS (cont.)

I	Iodine
In	Indium
K	Potassium
kg	Kilogram
ℓ	liter
La	Lanthanum
LC	Lethal Concentration
LD	Lethal Dose
Li	Lithium
m^3	cubic meter
MATE	Minimum Acute Toxicity Effluent
MEG	Multimedia Environmental Goal
Mg	Magnesium
mg	milligram
mℓ	milliliter
mm	millimeter
Mn	Maganese
Mo	Molybdenum
mp	melting point
mppcf	millions of particles per cubic foot (of air)
mrem	millirem
N	Nitrogen
Na	Sodium
NAAQS	National Ambient Air Quality Standards
NAE	National Academy of Engineering
NAS	National Academy of Sciences
Nb	Niobium

ABBREVIATIONS AND SYMBOLS (cont.)

NCI	National Cancer Institute
Nd	Neodymium
Ni	Nickel
NIOSH	National Institute for Occupational Safety and Health
NO_x	Nitrogen Oxides
NSPS	New Source Performance Standards
O_3	Ozone
OSHA	Occupational Safety and Health Administration
p	Phosphorus
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PCB	Polychlorinated biphenyl
PPAH	Particulate Polycyclic Aromatic Hydrocarbons
ppb	parts per billion
ppbc	parts per billion per carbon atom
ppm	parts per million
ppt	parts per trillion
Pr	Praseodymium
press	pressure
Pt	Platinum
R & D	Research and Development
Rb	Rubidium
ref.	references
Rh	Rhodium
RNA	Ribonucleic Acid
Ru	Ruthenium

ABBREVIATIONS AND SYMBOLS (cont.)

S	Sulfur
Sa	Samarium
SA	Simple Asphyxiant
Sb	Antimony
Sc	Scandium
Se	Selenium
Si	Silicon
Sn	Tin
Sr	Strontium
Ta	Tantalum
Te	Tellurium
Th	Thorium
Ti	Titanium
Tl	Thallium
TLm	Median Tolerance Limit
TLV	Threshold Limit Value
TSS	Total Suspended Solids
U	Uranium
UV	Ultraviolet light
V	Vanadium
vap. d.	vapor density
vap. press.	vapor pressure
vol.	volume
W	Tungsten
WLN	Wiswesser Line-Formula Notation
wt	weight

ABBREVIATIONS AND SYMBOLS (cont.)

Y	Yttrium
yr.	year
Zn	Zinc
Zr	Zirconium
μ	micron
μg	microgram
μℓ	microliter
μci	microcuries

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SECTION 1

INTRODUCTION

Multimedia Environmental Goals (MEG's) are levels of significant contaminants or degradents (in ambient air, water, or land or in emissions or effluents conveyed to the ambient media) that are judged to be (1) appropriate for preventing certain negative effects in the surrounding populations or ecosystems, or (2) representative of the control limits achievable through technology. MEG's are projected for more than 650 pollutants. This list, to be expanded and revised as emergent data warrant, was compiled on the basis of descriptions in the literature of fossil fuels processes and of hazardous substances. More than 200 of the projected 650 candidates receive full attention here; the remaining substances will be considered in a supplement to this report.

In the context of deriving MEG's, the report attempts: (1) to offer some perspective on the broad range of possible contaminants whose control is of vital interest to both industry and the public; (2) to further develop and define indicators designating which contaminants must be given priority consideration both for immediate control and for subsequent research; (3) to bring existing and emerging data together in a format that is efficient for use in environmental assessment; and (4) to explore some basic methodologies which provide the present goals, and which also suggest directions for more refined methodologies or studies in specific areas.

1.1 MEG's METHODOLOGY

To meet the need for a workable system of evaluating and ranking pollutants for the purpose of environmental assessment, the Research Triangle Institute has initiated the development of a technical approach which can be used to delineate MEG's for a large number of compounds. The system allows extrapolation of certain required data (which are generally available in one form or another for most compounds) through simple models. Several of the models incorporated in the MEG's methodology were developed or suggested by previous researchers; other models were designed or modified specifically for application in this report. While the rapid increase in the volume of data accessible in recent months has increased the reliability of assessment schemes based on modeling techniques, data gaps remain a problem. These gaps make it impossible to provide, for every substance addressed, goals for each of the three media on the basis of all models. However, when provision is made for utilizing data in a variety of forms from a variety of sources, it becomes possible to describe MEG's which are reasonable for many chemical substances based on at least some of the selected criteria. As a result of this adaptability, the methodology provides a practical, workable system for determining meaningful goals in an ever increasing percentage of cases.

Both ambient level goals and emission level goals based on ambient factors are addressed in this report. Existing or proposed Federal standards, criteria, or recommendations are acknowledged as previously established goals and have been utilized wherever applicable. For those substances not addressed by current guidelines, empirical data indicating

(1) toxic potential (both acute and chronic) as well as (2) the reactions and associations of the substance within the various media, (3) natural background levels, and (4) the conditions under which the substance may be emitted and dispersed have been utilized for the purpose of describing MEG's. In every case care has been taken to arrive at conservative but reasonable figures based upon reliable and available data while considering an array of possible options.

Consideration in arriving at ambient level goals was given to (1) existing Federal standards or criteria, (2) established or estimated human threshold levels, (3) acceptable risk levels for lifetime human exposure to suspected carcinogens or teratogens, (4) degrees of contamination considered reasonable for protection of existing ecosystems, and (5) cumulative potential in aquatic organisms, livestock, and vegetation. It is recognized that there are several other criteria pertinent to ambient level goals that have not been incorporated into the methodology developed here (for example, synergisms, antagonisms, and other secondary pollutant associations); new research is needed before more refined models of estimation can be developed to allow inclusion of these criteria.

In estimating goals for emission levels, the methodology developed in this report was designed to make use of (1) the concentrations described as ambient level goals based on hazards posed to public health and welfare as a result of long term or continuous exposure to emissions; (2) natural background levels which provide goals for elimination of discharge; (3) and hazards to human health or to ecology induced by short term exposure to emissions. Values for the last criterion were estimated as Minimum Acute Toxicity Effluents (MATE's) which are intended to serve both as relative hazard indicators and as estimated levels of effluent contaminants considered to be safe for short term exposures. The MATE values provide an increasingly useful tool for comparisons in environmental assessment. Again, the need is clear for further research and development of simple but effective models incorporating data pertinent to (1) quality of the receiving media before introduction of the substance, (2) characteristics of transport and dispersion of emissions, (3) considerations of location and abundance of sources emitting a given pollutant, (4) numbers of populations affected, and (5) secondary pollutant formations.

A proposed follow-up report on technology-based emission level goals will focus on estimated levels of control achievable through application of best available or best practicable technology. Anticipated and developing technology and technology transfer will also be considered.

It is understandable that some readers may question the reliance on Threshold Limit Values (TLV's)® in the methodology developed for describing MEG's. The TLV's, established by the American Conference of Governmental Industrial Hygienists (ACGIH) as guidelines for prevention of adverse occupational exposures, are based on both animal studies and epidemiological findings and inferences, and they represent the opinions of experienced physicians, toxicologists, and industrial hygienists. We acknowledge the fact that the ACGIH has made clear its intention that the TLV's are to be used solely in the practice of industrial hygiene; it does not recommend their use as a relative hazard index or in continuous exposure applications. However, (because the TLV's (1) comprise the most comprehensive body of recommendations currently available regarding levels of human exposure to chemical contaminants; and (2) are widely accepted as valid indicators of permissible levels for occupational exposure) in the continuing absence of data more reliable than the TLV's, their use in the MEG's methodology, balanced as it is by consideration of such a wide array of other factors, seems well justified.

1.2 ORGANIZATION

The sections which follow this introduction relate the current state of progress in the development of the MEG's approach as a tool for environmental assessment. Conclusions and recommendations that are drawn from this study appear in the next section. Section 3 offers some background on the present scope of the project, the criteria by which substances were chosen for the master list, the purpose of the current list arrangement, and the development of the MEG's chart. The rationale behind the format chosen for the "Background Information Summaries" is discussed in Section 4, along with tabulations describing the types of data assembled on those pages and their significance with respect to MEG's.

Sections 5 and 6 provide explanations of the values which constitute entries in the MEG's charts. Section 5 on Ambient Level Goals explains the methodology developed for estimating permissible concentrations for chemical substances. Estimated Permissible Concentrations

(EPC's) serve as a basis for comparison of diverse pollutants and provide an important foundation for MEG's. The rationale behind Minimum Acute Toxicity Effluent levels (MATE's) and the models developed for describing MATE's are presented in Section 6. Emission Level Goals for "Totals" (including particulates and hydrocarbons for air, and biological oxygen demand [BOD], chemical oxygen demand [COD], total dissolved solids, total suspended solids, and total organic carbon for water) are also discussed. Emission levels goals based on acute toxicity along with other factors are suggested as ceiling levels for hydrocarbons and particulates. (Recommendations for the water Totals are still in development stages.)

Section 7 discusses a system developed to assign through a numerical system hazard indicators for chemical substances on the basis of the estimated permissible concentrations for those substances in air. These indicators, designate the pollutants most dangerous to human health with the figures "X," "XX," and "XXX" in order of increasing hazard potential. The system was developed to distinguish quickly those substances deserving high priority attention. Finally, Section 8 offers some other possible applications for the MEG's methodology and the derived values and suggests extensions of MEG's for future work.

The appendices present the bulk of the data itself. Appendix A provides a brief explanation of the categories designated for classifying pollutants. These categories have been assigned on the basis of structural similarities and/or functional relationships and serve to logically organize the Master List. An organization scheme such as this allows comparisons of the relative hazard of related substances within categories as well as between compounds of different categories.

The Master List of Chemical Substances and Physical Agents is presented as Appendix B. Appendix C tabulates MATE's for all the master list entries for which the necessary data is readily available. Appendix D presents results of application of the system described in Section 7 for calculating hazard indicators. Hazard potential values for 216 chemical substances are included.

Appendix E presents Background Information Summaries and MEG charts for 216 chemical substances, addressed in the order of their category listing. Appendix F supplements this arrangement by providing an alphabetical cross-reference of the substances including all the synonyms by which a potential user of the compilations might be familiar with a particular compound. This system should allow easy access for those seeking information on a single specific susbstance, while retaining the benefits of category organization for comparisons between substances.

Appendix G offers a brief overview of research into chemical carcinogenisis, an area which in recent years has assumed an important role in determining degrees of concern over potential pollutants. As evidence mounts that chemical contamination induces the majority of human cancers, recognition of the areas of general agreement in theories regarding carcinogenisis becomes exceedingly relevant to any evaluation of toxic substances.

1.3 OBJECTIVES

Responsibility for definition of desirable levels of contaminant control within the United States lies primarily with the Environmental Protection Agency (EPA), which provided funding for this project.

The original intent of this work was to describe MEG's for chemical pollutants associated with fossil fuel processes (primarily coal conversion processes. However, recognition of the value of an expanded list of contaminants and the potential for extended application of the methodology for establishing MEG's has called for the development of a broad, systematic, and adaptable approach for addressing still a larger number of chemical and non-chemical pollutants.

It is expected that this initial report addressing multimedia environmental goals will provide a springboard for further research in developing MEG's. The goals suggested here and their organization should supply immediate benefits for those involved in environmental evaluation and assessment programs. The methodology developed is designed to allow incorporation of substantial new data as it becomes available; it should also stimulate exploration into more sophisticated approaches which make use of empirical data evolving from research efforts currently in progress.

It must be emphasized that this volume is by no means intended to be a final product of research into multimedia environmental goals; indeed, we wish rather to underscore the need for extensive future research not only to provide more exact and advanced data, but to refine this type of methodology and to examine new and different systems related to it. In making available this first attempt at developing and utilizing a methodology for the purpose of describing selected multimedia environmental goals, we hope, at the very least to generate discussion of procedures for improving upon the accuracy and viability of the approach and the models used in this report.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The methodology developed herein, although based on numerous assumptions, is effective for describing meaningful MEG's for most of the compounds addressed. The significance of the methodology lies not in any specific model, but in the array of models which allows MEG's to be defined on the basis of a variety of data items.

While a rapid increase in volume of data accessible in recent months has increased the reliability of assessment schemes based on modeling techniques, data gaps remain a problem. These gaps make it impossible to provide, for every substance addressed, goals for each medium on the basis of all the applicable models. However, when provision is made for utilizing data in a variety of forms, it becomes possible to describe MEG's which are reasonable based on at least some of the selected criteria. As a result of this adaptability, the methodology provides a practical, workable system for determining goals in many cases. Of the 216 substances addressed, only 6 emerge with no numerical MEG values, providing a good indication that the methodology is sufficiently broad in its bases to provide the comparison criteria needed for environmental assessment.

Goals derived from the methodology appear to be viable ones for air and water although the values for land are probably overly conservative.

In general, the values presented as ambient level goals are higher (with a few exceptions) than the values reported as natural background concentrations.

The MEG's should not conflict with efforts currently underway to fully characterize the toxicological and environmental significance of specific substances. Instead, the two areas should compliment one another. The MEG's offered in this report are not intended to supercede individual EPC or MATE values established by subjective investigation. Contradictions between MEG's derived through the methodology and those based on novel but valid data should be eliminated so that only the most specific relevant data serve as the basis for MEG's. For example, epidemiological data where available should outweigh animal toxicity data as a basis for establishing MEG's. There do not appear to be serious contradictions of this type for the MEG's reported here. However, as the methodology is applied to more and more substances, the potential for contradiction increases. In view of this possibility and considering the large number of assumptions inherent in the derivation of MEG's, it would be wise to subject the entire array of values obtained to review by a panel of toxicologists and epidemiologists. Although sufficient information for properly evaluating chemical hazards is available for only a small percentage of the Master List Compounds, a subjective review is still warranted, especially since the emphasis in this report has been placed on developing the methodology rather than on exhaustively studying selected compounds or elements.

The juxtaposition of information, gleaned from diverse sources, on MEG's charts effectively facilitates analysis and decision making concerning the potential impact of a pollutant on health and on the environment. The medium of greatest importance for a particular substance may become evident, as in the case of the phenolic compounds. The type of effect or impact likely to result first from effluents containing excessive quantities of a particular pollutant also may be discerned from the MEG chart for that pollutant. For example, it may be indicated that aquatic life will be affected by water containing the pollutant before human health hazards arise. Dangers of oncogenic or teratogenic effects, as opposed to more readily evident kinds of effects that might be associated with a compound, are also pointed out by the MEG's.

The categorization system for organizing the Master List entries has proven to be highly effective for resolving the list into a useful network relating chemical substances. Each category is characterized by toxicologically and chemically similar substances. Extrapolations and generalizations among substances within a category are practical and valid, often allowing data gaps to be filled.

The format developed for presenting summarized information is conducive to computer programming and such programming should proceed as the next step in MEG's development. Data manipulation and update will be greatly facilitated by computerization of the background information summaries for MEG's. Also the MEG's Master List should be updated on a regular basis to reflect the latest data arising from current analytical research, particularly in the area of coal conversion.

The system for assigning hazard indicators on the basis of human health effects from air exposure has provided a reasonable distribution and some interesting insights. Similar schemes for describing toxicity indicators on other bases could be developed.

The use of models for translating animal toxicity data into EPC's or MATE's requires that certain assumptions be made. A worst case approach has been taken to keep the MEG values conservative. Generally, MEG's derived from models which use LD_{50} or other acute toxicity animal data are more conservative than MEG's based on TLV's or NIOSH recommendations. Use of oral LD_{50} values in certain of the models introduces new variables into the system since:

1) Oral absorption factors are almost always less than one.
2) Oral absorption factors are generally lower than inhalation absorption factors (inhalation will be the primary route of absorption for human exposure).
3) Detoxification often occurs to some extent for ingested toxicants.

Because of these unknowns, liberal safety factors are incorporated in the models using the animal LD_{50} data.

In addition to the assumptions required for translating animal data to human health effects, arbitrary constants are employed in several cases as safety factors.

In future refinement of the MEG's methodology, a model which utilizes animal toxicity data expressed as concentrations (LC_{50} or LC_{Lo}) should be developed. Since LC_{50} and LC_{Lo} are not widely available, a correlation might be established between concentration values and LD_{50}'s to provide a derived LC_{50} as a basis for widely applicable model. An array of land models for deriving EPC's and MATE's needs to be developed to take into consideration:

1) direct ingestion by animals;
2) contact with other media (air, water);
3) ingestion of vegetation grown on contaminated soil by humans and animals; and
4) contact and/or ingestion by soil microorganisms.

Several problems have been encountered in compiling the data for the background information summaries. Surprisingly little has been done in the past to correlate natural air, water, and land concentrations for the various contaminants. This is an area in vital need of attention. Efforts to compile and collate existing measurement data should continue. Information from chronic effects studies is also difficult to locate as are biological half-lives and inhalation or ingestion absorption factors.

One of the primary problems encountered in organizing information pertinent to polycyclics is nomenclature. These compounds have been named inconsistently in the literature for many years. Several systems for naming the compounds have been used, and coordinating the names and structures is a persistent problem. Errors and inconsistencies occur in several references, so it is obvious that we are not the first to encounter such problems.

Some difficulties arise in assigning adjusted ordering numbers to indicate carcinogenic or teratogenic potential. For situations in which contaminant levels in workrooms have resulted in increased cancer incidences in workers, it is often impossible to determine the effective dosage.

Thus an adjusted ordering number could not be calculated. A mechanism for including such data into the MEG's needs to be developed. Another problem also arises with respect to the tests performed to determine carcinogenicity. In a number of cases, tests were carried out with a mixture of substances and thus cannot be interpreted as evidence of carcinogenic potential for a single compound. Where such data are available for mixtures, it might be well to incorporate that mixture into the MEG's Master List.

There are, within the MEG's for chemical substances presented here, numerous gaps. These gaps result from either (1) the nonexistence of the required data; or (2) its existence in other than the readily available literature. It was the purpose of this study to make the most use of readily available data, hence in-depth searches into the journals of chemistry and toxicology were not performed. This remains to be done and will very likely yield data to allow numerous gaps in the charts to be filled. In-depth literature research relative to synergisms, antagonisms, specific compound associations, epidemiological studies, and results of bioassay studies of complex effluents should be conducted simultaneously. Also nonchemical degradants such as heat, noise, land usage, water usage, subsidence, and visual effects should be investigated. Models should then be developed to incorporate this data into the MEG's methodology to further improve the reliability of the system.

SECTION 3

DEVELOPMENT OF MULTIMEDIA ENVIRONMENTAL GOALS (MEG'S)

The establishment of Multimedia Environmental Goals (MEG's) as estimates of desirable ambient and emission levels of control is an integral part of EPA's environmental assessment approach. Recent emphasis upon assessing impact throughout the entire biosphere has evolved from the EPA policy of having a single laboratory address all media receiving effluents from a particular industry. This policy has been adopted to provide a coordinated and efficient approach for the control of industrial emissions.

The MEG's work represents an important step in EPA's efforts to address systematically many chemical substances for the purpose of establishing priorities for environmental assessment programs. By establishing MEG's, the need is met for a ranking system to provide decision criteria in source assessment. The MEG's may also be used for establishing priorities among the pollutants to be ultimately addressed by regulations, and thus, may influence control technology development in the future.

3.1 OBJECTIVES

Originally, efforts to establish MEG's were aimed at pollutants associated with synthetic fuels processes, the main objective being the collation of the existing Federal standards, criteria, or recommendations for those pollutants. The scope of the project was expanded, however, to encompass a broad range of objectives. The objectives, established during the course of the MEG's work include the following:

1) Compile a Master List of all chemical contaminants, complex effluents/mixtures, and nonchemical degradants (such as visual effects, subsidence, heat, and noise) to be addressed by MEG's. The list is to include but should not be limited exclusively to those contaminants and degradants from fossil fuels processes.

2) Arrange the chemical substances appearing on the Master List into a practical catalog to provide a useful tool for environmental assessment.

3) Design a format conducive to the concurrent presentation of both Emission Level Goals and Ambient Level Goals for a myriad of chemical substances. The format should allow ready comparison of MEG's for different substances.

4) Design a format for presentation of background information pertinent to MEG's for each chemical substance.

5) Develop a methodology to establish meaningful values to serve as MEG's for each chemical substance on the Master List in the absence of existing or proposed Federal guidelines. The methodology should incorporate as MEG's those Federal standards, criteria, and recommendations pertinent to chemical substances. The following steps were envisioned:

   Assemble and collate all existing or proposed Federal guidelines pertinent to each chemical substance on the Master List.

   Define models to translate empirical data into estimated no-effect continuous exposure levels for chemical toxicants in air, water, and land.

   Define models to translate empirical data into values describing Minimum Acute Toxicity Effluents (MATE's) for chemical substances in air, water, and land.

   Suggest values to describe certain "Totals" in Minimum Acute Toxicity Effluents.

   Describe dilution factors applicable to various specific emission situations in order to establish a range for expected dilution factors.

6) Develop hazard indicators to designate "high priority" chemical contaminants on the basis of the assigned MEG's.

7) Present an array of MEG's for each chemical substance appearing on the Master List on the basis of existing Federal guidelines or empirical data.

These objectives have all been addressed and have, for the most part, been satisfied within this MEG's report (although not all the chemical substances are herein addressed, the mechanism for providing MEG's for additional substances is established, and a MEG's supplement addressing the remaining compounds and elements will be forthcoming).

We wish to acknowledge that these objectives have been established and accomplished as a result of close coordination and cooperation with EPA personnel, particularly during the development stages of the program.

3.2 COMPILATION OF THE MASTER LIST OF CHEMICAL SUBSTANCES AND PHYSICAL AGENTS

A Master List of chemical substances and physical agents has been compiled using selection factors prescribed by EPA. Primary emphasis in selecting Master List entries has been placed on contaminants from fossil fuels processes since the funding for the MEG's work has been provided by the Fuels Process branch of IERL/EPA. Fossil fuels processes encompass synfuels processes (including gasification and liquefaction of coal and coal cleaning) oil refining, and fossil fuels utilization processes. The Master List has been compiled on the basis of the literature pertinent to these processes. Process streams were characterized both qualitatively and quantitatively wherever possible to provide insight for selecting substances likely to be present but not mentioned specifically in the process literature.

All chemical substances in the Master List are addressed by MATE's in this report, and MEG's for 216 selected substances are addressed. MEG's for the remainder of the substances on the Master List will be the subject of a future supplement.

Three levels of priority were assigned to the selection factors to determine what substances, of all possible chemical substances and physical agents which might be described as environmental contaminants, would be entered on the Master List for MEG's. The selection factors are described below.

3.2.1 Primary Selection Factors

All those individual substances or classes of substances that are known or suspected to be present in the emissions or effluents from fossil fuels processes are to be included on the Master List. Since, in addition to specific individual compounds, several general classes of chemical substances (for example, cresols) are identified in that literature, secondary selection factors are applied to select representative or characteristic compounds from identified chemical classes in a systematic manner.

3.2.2 Secondary Selection Factors

Chemicals satisfying one or more of the secondary selection factors are to be included on the Master List if they are members of general chemical classes associated with fossil fuels processes. In other words, compounds that meet any one of the four secondary selection factors and are representative of a class of compounds associated with fossil fuels processes must appear on the Master List.

Secondary selection factors are:

1) Federal standards or criteria exist or have been proposed (ambient, emission, or occupational).
2) A TLV has been established or an LD_{50} has been reported.
3) The substance has been listed as a suspected carcinogen.
4) The substance appears on the EPA consent Decree List.

In some cases isomeric or closely related compounds that are likely to occur together in emissions and to behave similarly have been included as one entry on the list (for example, the ortho, meta, para cresols).

3.2.3 Tertiary Selection Factors

Consideration for inclusion in the Master List is also to be given to certain additional pollutants, not necessarily associated with fossil fuels processes, provided they satisfy either of the tertiary selection factors: (1) the substance is present as a pollutant in the environment or (2) the substance has been identified as being highly toxic.

Discretion has been exercised in adding substances to the list on the basis of tertiary selection factors, and, in fact, only a few contaminants that are not related to fossil fuels processes (for example, PCB's) have been included on the current Master List. Drugs and pesticides have been purposely omitted.

3.3 ORGANIZATION OF THE MASTER LIST

More than 600 chemical substances meeting the prescribed selection criteria have been entered on the Master List; to organize such a long list, a system for arranging the substances had to be developed. The system ultimately determined to meet the need for organization most effectively involves clustering substances into categories corresponding to chemical functional groups for organic compounds and by principle element for inorganics. The categories are then arranged to provide a coordinated framework for the list. This categorization scheme, besides organizing the list of chemical contaminants into manageable chunks, emphasizes logical relationships between groups of substances so that each category is characterized by toxicologically and chemically similar substances.

Generalizations and extrapolations are often valid among the compounds included within a category allowing data gaps to be filled in some instances. Substances likely to occur together or to behave similarly in an organism often become apparent through the categorization scheme. Methods of detection for compounds within a specific category are likely to be similar. Furthermore, analysis of a category as a whole is, in some cases, practical and may be a valuable technique for broad screening applications.

The categorization scheme allows one seeking information on a particular substance to find material of value from a related compound or element, should the particular item of interest be missing from the compilations. The usefulness of isolating related compounds by categorization has become very evident during the course of data collection for the current MEG's work. For example, phenolic compounds are addressed collectively by water quality recommendations. The categorization approach for organizing the Master List is compatible with two different philosophies within the context of environmental assessment. It has been reasonably argued that in light of the complex mixtures and possible synergistics of pollutants issuing from industrial sources, and the complicated associated epidemiology, it becomes more viable to control pollutants as broad groups rather than single compounds. On the other hand, the properties and activities of single compounds must be understood to make the task of categorization a manageable one, to allow specificity when it is significantly more efficient, and finally, to understand the anomalies to group similarity which inevitably crop up. Certainly categorization can be useful to (1) environmental monitors who must take grab samples; (2) engineers who are aware of the association of groups of distinct chemical substances with specific plant operations; and (3) chemical analysts whose instrumentation may be set up for analysis of specific groups.

The arrangement of the MEG's Master List is very important since the order in which compounds or elements appear on the Master List determines the order of their presentation in the MEG's compilations (i.e., MEG's charts with corresponding Background Information Summaries). The current Master List including Organic Compounds, Inorganics, and Physical Agents is contained in Appendix B.

An alphabetical arrangement of Master List entries, although in some ways the simplest approach to organizing the list has been avoided since it would provide no means of associating related compounds (unless of course their names begin with the same letter).

3.3.1 Organization of the Organics List

The organic compounds appearing on the MEG's Master List have been organized into categories on the basis of chemical functional groups. Categorizing organic compounds by functional group means assembling together those compounds possessing a particular atom or group of atoms likely to comprise the site for a chemical reaction. Arranging organic compounds by functional groups is quite a logical solution to organizing the list since, due to common structural features, compounds within a category will display marked similarities in their solubilities, chemical reactivities and biological manifestations. (Of course, there are some compounds on the list that, because of multiple functional groups, do not fit precisely into a single category. Such compounds were assigned to specific categories on the basis of their predominant [most reactive] sites. Judgement in assigning some of these compounds to categories had to be exercised, since the predominant function could vary with temperature, nature of solvent medium, other chemicals present, etc.)

Upon assigning all the organic compounds to their respective functional group categories it became apparent that 26 organic categories would be required to organize the entire organic list. To further organize the compounds, some of these 26 categories were divided into two or more subcategories, based on more detailed structural features or toxic similarities. The 26 designated organic categories are tabulated in Appendix A and discussions of each category and the significance of its functional group are presented.

The organic categories have been arranged to mimic the system used by various textbooks introducing organic chemistry thus setting up an orderly procession of organic compounds proceeding from the simplest alkanes to highly complex organometallics.

Certain groups of compounds such as the amino acids and sugars do not appear in the list of organic categories. Such compounds are not of primary importance from the environmental assessment standpoint and have thus been omitted. If specific compounds from groups such as these should prove to be important, they may be entered in the list according to their primary functional group (for example, sugars may be designated aldehydes or alcohols and amino acids, as either amines or acids).

3.3.2 Organization of the Inorganics List

Organizing inorganic substances into a logical, meaningful index for environmental assessment programs poses a different problem from that encountered in arranging organic compounds. Classification of inorganics by element is one obvious solution which would allow for inclusion of every Master List entry, but simply categorizing all the entries by element would not reveal similarities among salts or compounds of different elements. Since it is desirable to order the substances to indicate such similarities and to establish patterns among compound formation as often as possible, the most effective arrangement for the Master List inorganics was determined to be the following:

1) Categorize all entries by the predominant or parent element.

2) Arrange the element categories in groups corresponding to their periodic groups.

It is difficult to improve upon the fundamental periodicity of the atoms as a logical arrangement of elements.

To implement this organization scheme, all inorganic substances appearing on the Master List have been classified according to the predominant parent element, i.e., the element that most characterizes or influences the properties of the substance. Each element, or element series (in the case of the lanthanides and actinides) occurring in one of the inorganic Master List entries, then, constitutes a separate category. Altogether, 51 categories are required to organize the entire list of inorganics. Although this large number of inorganic categories makes the list somewhat cumbersome, it insures that objective consideration will be given to every element significant enough to be included in the list compilation.

The 51 categories so obtained are arranged into groups which reflect the columns or groups defined by the periodic law of the atoms. This law is best exemplified by a periodic chart of the atoms in which atoms are presented in rows from left to right in the order of their atomic numbers (i.e., the number of protons in the nucleus). A new row in the chart is begun wherever sharp transitions of atomic structure begin. Altogether, seven horizontal rows or periods are established and aligned under one another forming vertical columns of atoms. These columns called groups are highly significant in that atoms within a column

Within a given category, Master List entries are listed as elemental species, (zero valence state), ionic species formed, and significant compounds or salts. It should be noted that the term "ion" has been used loosely in this regard to designate truly ionic species and also oxidation states in complex ionic species.

The list of inorganic categories presented in the order in which they appear on the current MEG's Master List is contained in Appendix A. An alphabetical index to the inorganic categories is also included in Appendix A for convenience. In addition, a periodic chart is provided to further clarify the relation of the various atoms to one another.

This plan for organizing the inorganic substances was finally settled on after careful consideration was given to a variety of other approaches. Among the other organization schemes developed was a process approach (addressing synfuels processes) which offers an interesting and useful alternative inorganics list arrangment. This method for organizing the inorganics is presented briefly at the end of Appendix A as a supplementary categorization scheme.

3.3.3 Organization of the Physical Agents List

The term physical agents as used here includes nonchemical agents, such as heat and noise, which induce biological manifestations, as well as certain complex and chemically nonspecific substances which may be described as pollutants. Entries in the physical agents list of the MEG's Master List are categorized on the basis of their chemical or nonchemical nature. The entries in each category are then simply alphabetized.

generally have the same number of outer shell electrons. Because of this, the atoms contained in a given column will resemble one another with respect to valence state(s), crystal form, and chemical and physical behavior. Nine primary groups of atoms are designated by the periodic law with a and b subgroups delineated for groups one through seven. All atoms in "a" subgroups have outer shell electrons corresponding to the number assigned the group. For example, atoms of group 1a have one outer shell electron. The inert gases comprise group zero; they have no unfilled outer orbitals (which is why they are inert). The a and b subgroups serve to further distinguish similar elements; the b subgroups begin in the fourth row for it is here that two sets of atoms occur within a period. The periodic law places two atoms in row 1, eight atoms each in rows 2 and 3, 18 in rows 4 and 5 and 32 in row 6. Period 7 remains incomplete. Fourteen atoms (numbers 58-71) of row 6 are set aside in a special series called lanthanides. Similarly atomic numbers 90-103 of row 7 are designated actinides and are also isolated from the main body of the chart. (Refer to Periodic Chart included in Appendix A.)

For atoms aligned within a column, specific chemical tendencies, such as the ease of formation of hydride, will systematically increase (or decrease depending on the property and column) from top to bottom. Atoms adjacent in a column are likely to be very similar in their compound formations. There are also certain similarities between atoms occurring adjacent to one another in periods, however, the overall pattern of atoms within a period is more complex than for the atoms of a column or group. It is for these reasons that elements categories are arranged by groups in the final organization of the inorganics Master List.

In future MEG's development, high priority should be given to expansion of the list of physical agents and to the development of a utilitarian arrangement for physical agents.

3.4 DEVELOPMENT OF MEG'S CHARTS

A MEG's chart has been designed to display concurrently Emission Level Goals and Ambient Level Goals for specific chemical contaminants in a consistent, easy to use format. The current version of the chart (shown in Figure 1 and used for the compilations in this report) has evolved during the course of the project and represents the current state of the MEG's development.

The MEG's chart consists of two interrelated tables, one addressing Emisson Level Goals and one addressing Ambient Level Goals. These tables are divided into columns, each column established to describe a specific basis for a set of MEG's, for example, Toxicity Based Ambient Level Goals (Based on Health Effects). Within each column, space is provided for concentration levels to be specified for air, water, and land in units consistent with those specified in the index column at the left. Only numbers will appear in the columns.

3.4.1 Emission Level Goals

Emission Level Goals presented in the top half of the MEG's chart actually pertain to gaseous emissions to the air, aqueous effluents to water and solid waste to be disposed to land. Emission Level Goals may have as their basis technological factors or ambient factors although Emission Level Goals based on technology are not treated in depth in this

MULTIMEDIA ENVIRONMENTAL GOALS

EMISSION LEVEL GOALS							
	I. Based on Best Technology		II. Based on Ambient Factors				
Category	A. Existing Standards	B. Developing Technology	A. Minimum Acute Toxicity Effluent		B. Ambient Level Goal*		C. Elimination of Discharge
	NSPS, BPT, BAT	Engineering Estimates (R&D Goals)	Based on Health Effects	Based on Ecological Effects	Based on Health Effects	Based on Ecological Effects	Natural Background*
Air, $\mu g/m^3$ (ppm Vol)							
Water, $\mu g/l$ (ppm Wt)							
Land, $\mu g/g$ (ppm Wt)							

*To be multiplied by dilution factor

AMBIENT LEVEL GOALS					
	I. Current or Proposed Ambient Standards or Criteria		II. Toxicity Based Estimated Permissible Concentration		III. Zero Threshold Pollutants Estimated Permissible Concentration
	A. Based on Health Effects	B. Based on Ecological Effects	A. Based on Health Effects	B. Based on Ecological Effects	Based on Health Effects
Air, $\mu g/m^3$ (ppm Vol)					
Water, $\mu g/l$ (ppm Wt)					
Land, $\mu g/g$ (ppm Wt)					

Figure 1. Current Version of the MEG's Chart.

report. Technological factors refer to the limitations placed on pollutant control levels by either existing or developing technology (i.e., equipment capabilities or process parameters). Examples of Emission Level Goals based on Best Practicable Technology are the Standards of Performance for New Stationary Sources. Control levels achievable through developing technology can be estimated on the basis of research and development goals.

Since there is obviously a relationship between emission concentrations and the resulting ambient pollution levels, it is reasonable to consider ambient factors when establishing Emission Level Goals. Ambient factors that might serve as the basis for Emission Level Goals include consideration of

1) Minimum Acute Toxicity Effluents (MATE's) -- concentrations of pollutants in undiluted emission streams that will not adversely affect those persons or ecological systems exposed for short periods of time.

2) Ambient Level Goals, i.e., Estimated Permissible Concentrations (EPC's) -- concentrations of pollutants in emission streams which, after dispersion, will not cause the level of contamination in the ambient media to exceed a safe continuous exposure concentration.

3) Elimination of Discharge (EOD) -- concentrations of pollutants in emission streams which, after dilution, will not cause the level of contamination to exceed levels measured as "natural background."

Columns are provided on the MEG chart under Emission Level Goals for each of these ambient basis.

MATE values that serve as Emission Level Goals are derived through models which translate empirical data for each specific chemical substance into concentrations describing minimum acute toxicity concentrations.

MATE's related to human health effects and those related to ecolcgical effects are presented separately in the MEG chart allowing a maximum of six MATE values to be specified for each substance addressed. To conserve space on the charts and also to facilitate comparison, the values are presented in scientific notation with E used to indicate 10 exponential. The methodology developed for calculating MATE values is presented in detail in Section 6.1.

Emission Level Goals based on EPC's referred to human health and to ecology are also presented separately in the MEG's charts. Again, six values may be specified from a given contaminant. These values are simply the most stringent values from the Ambient Level Goals presented in the lower half of the MEG chart and are to be multiplied by dilution factors. Since dilution factors are highly source specific and may range over several orders of magnitude no effort has been made to convert the Ambient Level Goals into actual effluent concentration limits.

The ultimate Emission Level Goal is to limit contaminant levels in waste streams to the extent that natural background concentrations in ambient media will not be increased. This would mean that the emission concentration for a particular contaminant (with appropriate dilution factors applied) should not exceed the level of that contaminant in ambient air, water, or land measured in areas containing only natural background concentrations, i.e., no anthropogenic contamination. Concentrations appearing in the column designated EOD under Emission Level Goals are reported levels of chemical species in rural atmosphere, surface waters, or typical soils. Where these concentrations are not reported, levels measured in urban or industrial atmosphere and in drinking water, groundwater, or seawater may be listed since they given at least some indication of background concentrations.

Table 1 shows the Emission Level Goal Section of the chart indicating foundations for the MEG values to be inserted.

3.4.2 Ambient Level Goals

The lower half of the MEG chart is designed to present three classifications of Ambient Level Goals. All of these goals describe estimated permissible concentrations for continuous exposure. The Ambient Level Goals presented in the chart are based on: (1) current or proposed Federal ambient standards or criteria; (2) toxicity (acute and chronic effects considered); and (3) carcinogenic or teratogenic potential (the term zero threshold pollutants is used for distinguishing the contaminants demonstrated to be potentially carcinogenic or teratogenic). The goals are referred to health effects or to ecological effects for the first two classifications. For those substances addressed by ambient standards or criteria, no effort is made to describe additional EPC's based on toxicity. Goals based on toxicity and on carcinogenic or teratogenic potential are derived from models which translate certain empirical data into EPC's for the various chemical species.

Table 2 shows the Ambient Level Goals section of the chart and indicates the sources of the values to be inserted. The methodology developed for deriving the Ambient Level Goals is presented in detail in Section 5.

TABLE 1. EMISSION LEVEL GOALS FOUNDATIONS

	EMISSION LEVEL GOALS						
	I. BASED ON BEST TECHNOLOGY		II. BASED ON AMBIENT FACTORS				
	A. Existing Standards	B. Developing Technology	A. Minimum Acute Toxicity Effluent		B. Ambient Level Goal*		C. Elimination of Discharge
	NSPS, BPT, BAT	Engineering Estimates (R&D Goals)	Health Effects	Ecological Effects	Health Effects	Ecological Effects	Natural Background*
Air	Methodology not yet developed	Methodology not yet developed	Foundation: °$MATE_{AHS}$ °$MATE_{AH1(a)}$ °$MATE_{AH2}$ °$MATE_{AH3}$ °$MATE_{AC1}$ °$MATE_{AC2}$	Foundation: °$MATE_{AE}$	Foundation: °EPC_{AHS} °EPC_{AH1} °EPC_{AH3} °EPC_{AC1} °EPC_{AC2} °EPC_{AT}	Foundation: °EPC_{AE}	Foundation: °Rural background concentrations
Water			Foundation: °$MATE_{WHS}$ °$MATE_{WH1}$ °$MATE_{WC}$	Foundation: °$MATE_{WES}$ °$MATE_{WE1}$	Foundation: °EPC_{WHS} °EPC_{WH2} °EPC_{WC} °EPC_{WT}	Foundation: °EPC_{WE1} °EPC_{WE2}	Foundation: °Natural concentrations in surface waters °Concentrations measured in drinking water °Natural seawater concentrations
Land			Foundation: °$MATE_{LH1}$	Foundation: °$MATE_{LE1}$	Foundation: °EPC_{LH} °EPC_{LC} °EPC_{LT}	Foundation: °EPC_{LE}	Foundation: °Typical soil concentrations

TABLE 2. BASIC DATA AND DERIVATIONS FOR AMBIENT LEVEL GOALS

	AMBIENT LEVEL GOALS				
	I. Current or Proposed Ambient Standard or Criteria		II. Toxicity Based Estimated Permissible Concentrations		III. Zero Threshold Pollutants Estimated Permissible Concentrations
	A. Health Effects	B. Ecological Effects	A. Health Effects	B. Ecological Effects	Health Effects
Air	Basic Data: °Primary Ambient Air Quality Standard (existing or proposed) °Criteria for Hazardous Air Pollutant Emission Standards	Basic Data: °Secondary Ambient Air Quality Standard (existing or proposed)	Basic Data: °TLV °NIOSH Recommendation °LD_{50} (or substitute)	Basic Data: °Lowest concentration affecting sensitive vegetation (24 hrs)	Basic Data: °TLV (oncogenicity) °NIOSH Recommendation (oncogenicity) °Adjusted Ordering Number (species, route of administration, lowest effective dosage as carcinogen or as teratogen)
	Derivation: °Basic Data (EPC_{AHS})	Derivation: °Basic Data	Derivation: °$EPC_{AH1(a)}$ °EPC_{AH3}	Derivation: °EPC_{AE}	Derivation: °EPC_{AC1} °EPC_{AC2} °EPC_{AT}
Water	Basic Data: °Drinking Water Regulation or Criteria	Basic Data: °Water Quality Criteria Established for Protection of Aquatic Life	Basic Data: °TLV °LD_{50} (or substitute)	Basic Data: °Lowest Aquatic LC_{50} and Application Factor °Tainting Level °Application Factor or Hazard Level from Water Quality Criteria °Accumulation Factor and Allowable Flesh Concentration	Basic Data: °$EPC_{AC(1,2)}$ °EPC_{AT}
	Derivation: °Lowest value from Basic Data (EPC_{WHS})	Derivation: °Lowest value from Basic Data (EPC_{WES})	Derivation: °EPC_{WH2}	Derivation: °EPC_{WE1} °EPC_{WE2} °EPC_{WE3} °EPC_{WE4}	Derivation: °EPC_{WC} °EPC_{WT}
Land	Basic Data: °None available (in appropriate units)	Basic Data: °None available	Basic Data: °$EPC_{WH(S,2)}$	Basic Data: °$EPC_{WE(S,1,2,3,4)}$	Basic Data: °EPC_{WC} °EPC_{WT}
	Derivation: °None	Derivation: °None	Derivation: °EPC_{LH}	Derivation: °EPC_{LE}	Derivation: °EPC_{LC} °EPC_{LT}

The most stringent air, water, and land concentrations presented in the Ambient Level Goals portion of the MEG chart are repeated in the Emission Level Goals Section where they serve to describe (after application of the appropriate dilution factor) discharge concentrations.

3.5 DESIGN OF FORMAT FOR BACKGROUND INFORMATION SUMMARIES

A Background Information Summary is to accompany each MEG's chart supplying the data to substantiate the values appearing in the companion MEG's chart. The format for displaying the summarized data has been designed to present the data in a consistent logical fashion. The various classes of information to be specified in the summaries include:

- Identifying Information
- Natural Occurrence, Characteristics, Associated Compounds
- Regulatory Actions, Standards, Criteria, Recognition, Candidate Status for Specific Regulation
- Toxic Properties, Health Effects
- Minimum Acute Toxicity Concentrations
- Estimated Permissible Concentrations

A complete discussion of the Background Information Summaries is presented in Section 4.

3.6 DEVELOPMENT OF METHODOLOGY

The methodology developed for deriving MEG's incorporates existing and proposed Federal guidelines as well as models for translating empirical data into MEG's. The methodology addressing Ambient Level Goals as EPC's is discussed in detail in Section 5. The methodology for Emission Level Goals is presented in Section 6.

3.7 DEVELOPMENT OF HAZARD INDICATORS

A system has been developed for designating high priority air contaminants on the basis of human health effects. Section 7 explains this system which might serve as a model for additional indicators based on other criteria.

3.8 PRESENTATION OF MEG'S FOR MASTER LIST ENTRIES

Appendix E of this report contains the MEG's charts and Background Information Summaries for 216 Master List contaminants. Of these 216, only 6 emerge without numerical MEG values based on at least some of the criteria addressed by the methodology.

SECTION 4

BACKGROUND INFORMATION SUMMARIES FOR CHEMICAL SUBSTANCES

An obvious need in the field of environmental assessment has been for a useable instrument bringing together data related to environmental aspects of various chemical substances. The format developed for supplying summarized background information to accompany and substantiate MEG's charts has been designed to address this need, providing a large volume of information in a consolidated, consistent, workable arrangement. The format serves to organize existing and available data in a logical framework, yet at the same time it remains flexible enough to allow the future incorporation of emerging data. Arrangement of specific items of information in a consistent pattern and presentation of such data in conjunction with the corresponding MEG's chart allows the user to survey the data quickly and to relate Multimedia Environmental Goals to physical and chemical properties, associations, interactions, and toxicological characteristics of the element, compound, or group of compounds of interest. The data collected as background information for each substance is presented on a sheet designed to face the corresponding MEG's chart.

4.1 IDENTIFYING INFORMATION

Each summary is headed (on the left) by the category number assigned the substance on the basis of its characteristic functional group. (See discussion of categories in Section 3 and the synopsis of categories in Appendix A.)

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This category number serves to locate a specific compound within the total set of chemical substance compilations and to promote grouping of chemically and toxicologically similar substances. The preferred name for each substance, assigned according to the rules established by the International Union of Pure and Applied Chemistry (IUPAC), is displayed in capital letters immediately below the specified category number. The names issued by IUPAC's Commission of Nomenclature of Organic Chemistry[1] are recognized internationally by the Union's members, who include all the major scientific researching nations. The empirical chemical formula follows the preferred name for each substance. Major known synonyms are included in parentheses after the formula notation (All synonyms appearing on the background information summaries are included in the alphabetically indexed cross-reference comprising Appendix F).

A compact description of the substance in relative physical terms is provided beneath its name, furnishing information required by the casual observer to recognize the substance generally in its pure state.

To the right of the sections just mentioned, two specific structural identifications are supplied. The Wiswesser Line-Formula Notation, abbreviated WLN, gives a unique, unambiguous topological description of the structure of each substance. First published in 1954 and presently undergoing continuous reevaluation under the direction of the Chemical Notation Association, [2] this system is based on rules which allow for a complete linear notation revealing the components of the molecule and its architecture, as well as its configuration.

The constituents of this notation include the letter formulas normally used in chemical texts (with a few changes), numbers to describe the length of chains and rings, and certain additional symbols to represent key structural groups or bonding patterns. Because it efficiently translates unique three-dimensional structures into specific literal figures, the system is easily adapted for computer programming.

Beneath the WLN, a visual structural diagram is depicted in accordance with the orientation and numbering prescribed by IUPAC. Among other benefits, these visual representations allow comparison of isomeric compounds and illustrate functional similarites among compounds within a category. Various ionic species or possible valence states are indicated with the most commonly occuring structure underlined.

The arrangement of the identifying information just discussed, which appears at the top of each background information summary, is illustrated in Figure 2.

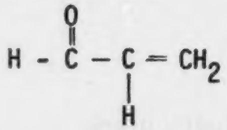
CATEGORY: 7A

WLN: VH1U1

ACROLEIN: C_3H_4O (acrylic aldehyde, propenal)

A colorless, yellowish liquid; disagreeable choking odor.

STRUCTURE:



$$H - \overset{\overset{O}{\|}}{C} - \underset{\underset{H}{|}}{C} = CH_2$$

Figure 2. Example of Substance Identification Data on Background Information Summaries

4.2 PROPERTIES

A more definitive compilation of physical and chemical properties appears just below the qualitative discription. Data supplied in this section, entitled "Properties" on the summaries, has been compiled (unless otherwise noted) from the following sources: the CRC Handbook of Chemistry and Physics;[3] the Merck Index;[4] Patty's Industrial Hygiene and Toxicology;[5] Sax's Dangerous Properties of Industrial Materials;[6] Polycyclic Hydrocarbons [7] by Clar; and the International Agency for Research on Cancer Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man.[8] The specific items of information reported under "Properties" on the summary sheets are listed in Table 3 along with clarifying remarks.

TABLE 3. PHYSICAL AND CHEMICAL PROPERTIES INCLUDED IN BACKGROUND INFORMATION SUMMARIES

Property*	Remarks
Molecular or atomic weight (Molecular wt., atomic wt.)	Weights are computed according to the International Atomic Values of 1961.
Atomic number (Atomic no.)	Atomic number is included for elements. It indicates the number of protons in the nucleus, and it determines the position of the atom on a periodic chart of the atoms. The atomic number also corresponds to the number of electrons in an atom of a particular element.
Periodic group (group)	The periodic group is the number assigned to the vertical column in which the element appears in a periodic chart of the atoms. The group numbers corresponds to the number of electrons in the outer shell of the atom. The fundamental periodicity of the atoms is universally accepted, and nine groups of atoms are specified.

*Abbreviations used in the summaries appear in parenthesis.

TABLE 3. (continued)

Property*	Remarks
Boiling point (b.p.) Melting point (m.p.)	Clarifying remarks such as "sublimes" are included where pertinent. Superscripts following the m.p. or b.p. indicate the pressure (if different from one atmosphere) corresponding to the reported value. All m.p. and b.p. are in °C unless otherwise noted.
Density (d.)	Normally expressed relative to the density of water. Specific gravity is indicated when the density is followed by superscript 20 (meaning the temperature of the substance is 20°C) and subscript 4 (indicating comparison to water density at temperature 4°C). For some substances reported in units specified such as g/l or g/ml.
Vapor density (vap. d.)	The density of a gas or vapor relative to the density of air (air assumed to consist of 80% N_2 and 20% O_2).
Vapor pressure (vap. press.)	Measures volatility of given substance at a given temperature. Expressed in millimeters (mm) of mercury (Hg) or in atmospheres. Temperature is indicated as subscript in °C or included in clarifying remarks.
Dissociation constant (pKa or pKb)	Ka is the dissociation constant of an acid compound indicating its potential to give up H^+ ion. Kb is the dissociation constant of a basic compound indicating its potential to give up an OH^- group. The "p" indicates that the constant is expressed as the negative logarithm of K. Subscript numbers after the a or b indicate the specific acidic or basic radical (in molecules with more than one possible ionization group) the constant pertains to.

*Abbreviations used in the summaries appear in parenthesis.

TABLE 3. (continued)

Property	Remarks
Valence states	Certain elements are capable of assuming two or more valence states, and these are specified. Reactivity, and thus, toxicity are often dependent upon the valence state of a given element.
Water solubility	Solubility is most often expressed in qualitative terms which carry no distinct numerical implications (for example, "slightly soluble in water"). The extent of the solubility is expressed in numerical terms (with temperature specified) in cases where the data are available.
Lipid solubility	Because lipids are important constituents of cell membranes, lipid solubility is a significant variable affecting transport of molecules within living systems. The property may be related to potential carcinogenicity by virtue of its influence on the ability of a substance to permeate a cell membrane.

4.3 NATURAL OCCURRENCE, CHARACTERISTICS, ASSOCIATED COMPOUNDS

Natural occurrence, characteristics, and associated compounds are cataloged on the background information summaries in the section after properties. Information in this section aids in relating potentially hazardous substances to sources of both emission and reception and suggests some of the important interactions, associations, and activities pertinent to each substance addressed. Data were culled from sources which include the NAS/NAE Water Quality Criteria,[9] EPA's Preliminary Assessment of Suspected Carcinogens in Drinking Water,[10] and an unpublished draft report to EPA offering a Compilation of Ambient Trace Substances[11] in air, among others. A listing of the types of data assembled in this area is presented in Table 4.

TABLE 4. INFORMATION SUPPLIED IN BACKGROUND INFORMATION SUMMARIES RELATING TO NATURAL OCCURRENCES, CHARACTERISTICS, AND ASSOCIATED COMPOUNDS

Types of Information	Remarks
Background levels in air	Concentrations of the various chemical species measured in air are included. Rural concentrations are reported most often and, in most cases, are indicative of natural background levels. Levels measured for urban or industrial locations are reported if available in the absence of data for rural sites. Units appearing in the reference source are entered; all values are converted to $\mu g/m^3$ for comparison, as well.
Background levels in water	Concentrations of various chemical species measured in surface waters of the U.S. at hydrologic bench-marks or other stations are included. Also, levels of chemical species identified in drinking water are included. Levels considered typical for seawater are reported as well.
Background levels in soil	Natural occurrence of various elements in the Earth's crust are reported as well as typical soil concentrations, if available. Values are in units of kg/Ha or in $\mu g/g$, or they are expressed as percentages.
Odor levels	Expressed as odor threshold, odor recognition level, or odor detection level. The precise definition of the three terms is elusive since the details of panel evaluations are involved. One study has defined odor recognition level as the level producing 100 percent recognition by the panel.

TABLE 4. (continued)

Types of Information	Remarks
Photochemical activity	Only minor qualitative remarks are included since the photochemistry for most compounds is highly complex and requires in-depth consideration to be of value.
Occurrence associations	Mineral associations or associations with coal or oil are specified. Also, related compounds and secondary pollutant formations are designated in some cases.
Dietary intake	Levels of consumption believed to be typical are reported for certain elements.
Characteristic chemical reactions and metabolic fate	Solubility in water, decomposition products and other reactions are mentioned. Although no effort is made to characterize fully the chemical or biochemical behavior of any substance, information regarded as essential to delineation of MEG's is included.

4.4 TOXIC PROPERTIES, HEALTH EFFECTS

Reported toxic properties and health effects influencing the goals and priorities derived in this report are compiled in the next section of the summary sheets. Sources which have gathered the experimental results reported in this section include the NIOSH Registry of Toxic Effects of Chemical Substances;[12] TLV documentation from ACGIH;[13] Patty's Industrial Hygiene and Toxicology;[5] Sax's Dangerous Properties of Industrial Materials;[6] specific NIOSH criteria documents, the NAS/NAE Water Quality Criteria[9] (in relating toxic effects on aquatic life); and the monographs published by the International Agency for Research on

Cancer entitled the Evaluation of Carcinogenic Risk of Chemicals to Man.[8] The specific data related to toxic properties reported consistently in the background information summaries is outlined in Table 43. Each of these types of data has been compiled previously by others and is largely available in tabulated form within secondary sources of information. Data related to synergisms and antagonisms has been included in the background information summaries in a few cases. However, such information is sparse, and until it is systematically compiled from a thorough survey of the literature, it will not be available in a form useable for consideration in establishing MEG's.

TABLE 5. TOXIC PROPERTY AND HEALTH EFFECTS INFORMATION INCLUDED IN BACKGROUND INFORMATION SUMMARIES

Types of data appearing on background information summaries	Specific items reported in background information summaries	Remarks
Animal toxicity infomation	LD_{50} - lethal dose (50% kill)	Generally expressed in mg of toxicant per kg of animal body weight. Reported whenever available for rat, dosage administered orally; LD_{50} for other route/species combinations are substituted depending on the availability. Only one LD_{50} is included for each chemical substance.
	LD_{Lo} - lowest published lethal dose	Generally expressed in mg of toxicant per kg of animal body weight. Reported when LD_{50} is not available. Preferred item is for rat, dosage administered orally.
	LC_{50} - lethal concentration (50% kill)	Generally expressed in mg of toxicant per m^3 of air, or in ppm. LC_{50} for at least one species (rat or mouse preferred) is reported if available.
	LC_{Lo} - lowest published lethal concentration	Generally expressed in mg of toxicant per m^3 of air, or in ppm. Reported when LC_{50} is not available.
Human health effects data	acute effects	Qualitative descriptions of effects including organ specificity and dosages, if available. Acute effects range from short-term intoxication to death and result from exposure(s) of short duration.
	chronic effects	Qualitative descriptions of effects including organ specificity and dosages, if available. Chronic effects are characterized by pathological tissue changes and result from prolonged or repeated exposures.

TABLE 5. (continued)

Types of data appearing on background information summaries	Specific items reported in background information summaries	Remarks
Human health effects data (continued)	biological half-life	Reported where available. An indication of the cumulative potential of a toxicant.
Data pertinent to carcinogenicity or teratogenicity	EPA/NIOSH ordering number	The four-digit ordering number indicates the relative degree of concern that might be warranted for a particular substance regarding its possible carcinogenic potential.
	affected animal species	
	recorded human effects	
	lowest effective dosages	
	adjusted ordering number	The adjusted ordering number is an indication of the carcinogenic potential which considers the lowest effective dosage.
Aquatic toxicity information	LC_{50} - lethal concentration (50% kill)	Expressed in mg per liter or in ppm of water. Species may be indicated, or value may be presented as a range for various sensitive species in various conditions.
or		
	TLm - tolerance limit median	

TABLE 5. (continued)

Types of data appearing on background information summaries	Specific items reported in background information summaries	Remarks
Aquatic toxicity information (continued)	bioaccumulation, or biomagnification (potential)	Expressed as the ratio of the possible concentration of a chemical contaminant within an organism to the concentration in the surrounding medium.
	reported tainting levels	Expressed in mg per liter or in ppm of water.
Phytotoxicity (plant toxicity) data	effective medium concentrations (air, water, or soil)	

4.5 REGULATORY ACTIONS, STANDARDS, CRITERIA, CANDIDATE STATUS FOR SPECIFIC REGULATION

The last section of summarized information lists the existing legal standards and proposed or recommended control levels for specific substances. Federal publications promulgate these regulations, ranging from congressionally mandated standards to the EPA Consent Decree List. Although major emphasis has been placed on the actions or recommendations of Federal agencies, recognition status by other agencies have been cited. The complete list of referred sources for this section of the Background Information Summaries appears in Table 6. The table has been organized to differentiate those actions which are enforceable for those that constitute recommendations or are specific designations related to toxic potential.

TABLE 6. REGULATORY ACTIONS, STANDARDS, CRITERIA, RECOGNITION, and CANDIDATE STATUS FOR SPECIFIC REGULATIONS CITED IN BACKGROUND INFORMATION SUMMARIES

Status of Citation	Specific Agency Publications Associated With Substance Recognition
Enforceable or proposed enforceable regulations	National Primary and Secondary Ambient Air Quality Standards (40 CFR, Part 50)
	National Emissions Standards for Hazardous Air Pollutants (40 CFR, Part 61)
	OSHA Standards for Hazardous Substances (29 CFR, Part 1910)

TABLE 6. (continued)

Status of Citation	Specific Agency Publications Associated With Substance Recognition
Enforceable or proposed enforceable enforceable regulations (continued)	National Interim Primary Drinking Water Regulations (40 CFR, Part 141)
	Public Health Service Drinking Water Standards (42 CFR, Part 72)
	EPA Toxic Pollutant Effluent Standards (40 CFR, Part 405-460))
	Regulations for Protection Against Radiation (10 CFR, Part 20)
	FDA Declaration
Significant Designations (recommendations not involved)	EPA National Emissions Standards For Hazardous Air Pollutants, Candidate List.
	EPA Toxic Pollutant Effluent Standards, Candidate List.
	Recognized water quality criteria.
	ACGIH recommendation.
	NIOSH recommendation.
	EPA Consent Decree List.
	NIC List of Carcinogens to Man.
	ACGIH designation as carcinogen, simple asphyxiant, or nuisance particulate.
	EPA Star Document Series subject.
	NIOSH Criteria Document subject.
	Chemical Industry Institute of Toxicology Priority Chemical Lists.

4.6 MINIMUM ACUTE TOXICITY EFFLUENTS; ESTIMATED PERMISSIBLE CONCENTRATIONS

At the bottom of each summary sheet, the actual calculations for both the Minimum Acute Toxicity Effluent (MATE) values and Estimated Permissible Concentrations (EPC's) of the substances are given to indicate the derivation of figures entered in the MEG charts. Only the equations defining the lowest MATE values in each medium are presented; (see Section 6-for a full discussion of the various models for deriving MATE's from different data sources.) For each substance addressed, all the pertinent EPC calculations as described in Section 5 are listed. By displaying these calculations, the Background Information Summary offers the reader the opportunity to relate the values listed on the charts to the data from which they are derived. The equations are presented in a consistent order so that their usage may be enhanced.

4.7 CONCLUSION

These summaries seek to provide as much pertinent information as is reasonable in as useable a format as possible. The aim is to meet the needs of the anticipated audience, which is expected to differ widely in background and experience with these substances and their associations. It is certain that the report will be applied in a number of different ways. The needs of those engaged in environmental assessment have been given first priority, and thus much of the summarized background information is arranged with its application in environmental analysis in mind.

Attempts will be made in future revisions of the background information summaries to update and to expand the data to incorporate emerging relevant items. Plans call for expansion of the section on physical and chemical properties to include specific data pertinent to methods of analysis or control techniques. Such properties as viscosity, ionization potential, magnetic and electrical properties, refractive index, and characteristic absorption bands should be added. Distinctive detection methods and their limits should be included in later versions in the section on natural occurrence, characteristics, and associations. Certain data (whose availablilty was limited for this version of the report but which should be included consistently in later revisions) can be appreciably expanded when the appropriate literature is surveyed. Mobility and residence times are two examples of such data to be added to the section on natural occurrences and characteristics; data on synergisms, antagonisms, sublethal toxic effects in aquatic life, and production of metabolites should also appear with more consistency in the section on toxic properties in the future. It is important also that results of epidemiological studies and inferences be added continuously to update the Background Information Summaries.

The format developed for presenting the summarized information is conducive to computer programming, which should proceed as the next step in MEG's development. Data manipulation and update will be greatly facilitated by computerization.

SECTION 5

AMBIENT LEVEL GOALS

To delineate Multimedia Environmental Goals for a variety of chemical substances, there is a need to establish a defined frame of reference for each substance to serve as a common basis allowing comparison of various characteristics among similar and diverse substances. Translation of various forms of data into Ambient Level Goals expressed as Estimated Permissible Concentrations (EPC's) reported in common units meets this need by facilitating comparison of relative hazard potential of possible toxic substances regardless of media, thus providing the opportunity to establish meaningful priorities for those substances.

An immediate application of these Ambient Level Goals arises in the logical relation of permissible concentrations of substances in ambient media to desirable levels of those same substances in emissions into the media. Since levels of most contaminants in emissions have an obvious causal relationship to the presence of those contaminants in ambient media, it is expedient to establish Emission Level Goals and Ambient Level Goals concurrently. Multimedia Environmental Goals (MEG's) charts have been designed to present in a concise tabular format levels of pollutants considered safe for continuous exposure within each medium; simultaneously, the charts present emission level goals based on both ambient and technological factors. Further discussion of Emission Level Goals and their relationship to ambient levels goals is found in Section 6.

A methodology for deriving Ambient Level Goals in the form of EPC's is presented in this section. EPC's are derived from three distinct data sources: the most stringent current or proposed ambient standards or criteria constitute one set of EPC's; empirical data concerning the effects of chemical substances on human health and the ecology are translated by models into toxicity-based EPC's; a third set of EPC's is derived from a system relating the carcinogenic or teratogenic potential of specific chemical substances to media concentrations considered to pose an acceptable risk upon continuous exposure. The systems used to derive MEG's from each of these data sources are discussed in detail in the following subsections.

The Background Information Summaries which accompany MEG charts present the equations used to define the EPC's and indicate by appropriate subscripts the precise medium, basis, and model for any EPC defined.

1) The first subscript letter denotes the medium addressed (A = air, W = water, L = land).

2) The second subscript letter indicates the application (H = human health effects, E = ecological effects, C = carcinogenicity, T = teratogenicity).

3) The third subscript may be the letter S indicating that the EPC reflects current of proposed Federal standard, criteria, or recommendation, or it may be a number indicating the particular model being applied. Model numbers are only assigned when more than one model has been described to translate a particular data base.

4) A fourth subscript, "a" indicates the EPC is expressed in ppm.

Examples of EPC subscript designation:

EPC_{AH1} *indicates the EPC is for air and is based on human health effects; it is calculated by the equation representing model 1 for air based on health effects other than carcinogenicity or teratogenicity.*

EPC_{WES} *indicates the EPC is for water and is based on ecological effects; it reflects a Federal standard on criteria.*

EPC_{AC2} *indicates the EPC is for air and is based on carcinogenicity; it is calculated by the equation representing model 2 for air, based on carcinogenic effects.*

5.1 ESTIMATED PERMISSIBLE CONCENTRATIONS BASED ON CURRENT OR PROPOSED AMBIENT STANDARDS OR CRITERIA

All existing or proposed Federal standards, criteria, or recommendations addressing chemical substances in ambient media are to be applied to define one set of Ambient Level Goals which takes precedence over goals derived from models discussed in subsequent subsections. When Federal guidelines include more than one value specifying permissible ambient levels for a given compound, the most stringent standard is reflected in the MEG chart as the EPC and is entered in the appropriate column under the general heading "Current or Proposed Ambient Standards or Criteria." Information pertinent to the standards or criteria utilized in establishing EPC's is presented in the background information summaries under the section entitled "Regulatory Actions, Standards, Criteria, Recognition, Candidate Status for Specific Regulation."

5.1.1 EPC's for Air Based on Current Ambient Standards or Criteria

The Clean Air act empowers EPA to establish both Primary and Secondary National Ambient Air Quality Standards [Ref. 40 CFR, Part 50] for a number of identifiable air pollutants. These standards, which must be based on recorded air quality criteria, are designed to protect against any direct adverse effects on public health (primary standards) as well as known or anticipated adverse effects on public welfare (secondary standards) ranging from ecological damage to destruction of property or loss of economic value. Primary standards appear in column A as EPC's based on health effects; secondary standards are specified in column B as EPC's based on ecological effects.

Additional regulations against emissions of certain very hazardous air pollutants are delineated in the National Emissions Standards for Hazardous Air Pollutants [Ref. 40 CFR, Part 51]. Present standards guard against undesirable emissions of asbestos, beryllium, mercury, and vinyl chloride which "have been shown to cause or contribute to an increase in mortality or to an increase in serious irreversible or incapacitating reversible illness." The language of the law makes it clear that these restrictions on emissions are based on the danger to public health posed by the presence of these substances in ambient air; hence, the levels specified as maximum ambient concentrations upon which the emission levels have been based appear as ambient level EPC's in column A based on health effects. The emissions standards themselves appear as Emission Level Goals based on ambient factors in the MEG charts for these substances.

To define the frame of reference for comparing these values, all the EPC's entered for air on the MEG charts are given in $\mu g/m^3$, and in some cases presented in ppm by volume at 25°C, 760 mm Hg and listed in parentheses immediately following the first number.

5.1.2 EPC's for Water Based on Ambient Regulations or Criteria

Standards or criteria applicable to drinking water indicate estimated permissible concentrations of contaminants based on human health effects.

Such regulations or recommendations are taken from the following: National Interim Primary Drinking Water Regulations [Ref. 40 CFR, Part 141]; U. S. Public Health Service Regulations on Drinking Water [Ref. 42 CFR, Part 72]; National Academy of Science/National Academy of Engineering (NAS/NAE) 1972 Water Quality Criteria [9] (for Public Water Supplies); and EPA Water Quality Criteria 1976 (Proposed)[14] (for Domestic Supplies).

Three sources of water quality criteria recommend levels of contaminants in water which might threaten aquatic life, and these recommendations furnish the EPC's for water based on ecological effects. The recommendations are those of the EPA (Water Quality Criteria [1976]);[14] the NAS/NAE (1972 criteria);[9] and the National Technical Advisory Committee (1968 Water Quality Criteria).[15] These criteria are based on the harmful effects to aquatic life resulting from exposure to contaminants in ambient water. These federally established criteria do not impose direct enforceable standards for specific substances; however, each State must establish regulations to restrict contaminant levels in navigable waters to comply with the Federal criteria.

Again, all entries are given in common units to allow comparison between substances. EPC's for water are expressed in μg/ℓ on the MEG charts.

5.1.3 EPC's for Land Based on Federal Recommendations

No Federal regulations have been established to limit concentrations of pollutants in soil, although the U. S. Department of Agriculture and Land Grant Institutions have recommended soil levels in kg per hectare for zinc, copper, lead, cadmium, and nickel.[16] These recommendations are not reflected on the corresponding MEG charts because they apply to specific soil types (as indicated by cation exchange capacity) and are not readily translatable to units consistent with those specified for soil in the MEG charts.

5.2 TOXICITY BASED ESTIMATED PERMISSIBLE CONCENTRATIONS

Levels of pollutants for continuous exposure in the various media which will not result in toxic effects to human health are dependent on the chemical, physical, and toxicological characteristics specific to each individual substance. The best procedure for determining such levels remains a thorough epidemiological investigation into the properties of substances of concern and evaluation of such data by experienced health effects researchers. Provided (1) that adequate data could be made available, and (2) that a judgment could be made representing a consensus of opinion among those knowledgeable in the field, the resulting estimated permissible concentration would supply the value sought as an ambient level goal. However, exhaustive research into all substances of environmental importance is impractical in light of the time and level of funding that would be required. Therefore, a less desirable, but more expedient method for establishing EPC's has been devised to provide, at least, a preliminary indication of permissible concentrations.

A system has been designed to provide these preliminary EPC's on the basis of empirical data which are available for a large number of chemical substances and which can be translated by application of appropriate models into concentrations expected to be acceptable for continuous exposure.

Some of the models used in the derivation of EPC's have been developed specifically for application in this report while others were developed previously by other researchers.

EPC's based on human health effects (other than carcinogenesis or teratogenesis) are entered on the MEG chart in column A under the general heading "Toxicity Based Estimated Permissible Concentrations;" EPC's based on ecological effects are entered in column B.

5.2.1 Toxicity Based EPC's for Air

EPC's for air have been specified on the bases of human health effects and on ecological effects.

5.2.1.1 EPC's for Air Based on Health Effects

Three models have been described to relate available empirical data to EPC's for air based on human health effects (other than carcinogenesis or teratogenesis). EPC_{AH1} (and, in some cases, EPC_{AH1a}) is calculated on the basis of TLV's or NIOSH recommendations and appears on the MEG chart provided the required workroom recommendations have been established or proposed. In the absence of a workroom air recommendation, both EPC_{AH2} and EPC_{AH3} are calculated provided a lethal dose to some animal species is available. In this case the EPC_{AH3} is listed on the MEG chart since it is a consistently lower value than EPC_{AH2}.

5.2.1.1.1 Model deriving EPC_{AH1} from TLV's or NIOSH recommendations -- Threshold Limit Values (TLV's),[17] established by the American Conference of Governmental Hygienists (ACGIH) and expressed as mg/m^3 or in ppm, are levels of contaminants which are considered by the conference to be safe for workroom atmosphere. More than 570 chemical substances have been addressed to date. The TLV's represent time-weighted exposure based on 8-hour/day or 40-hour/week exposure for working adults; they do not consider exposure to children (important because the ratio of tidal [breathing] volume to body weight for infants is approximately twice the ratio for adults [see Table 7] or exposure to persons with respiratory problems). To relate TLV's to continuous exposure concentrations, an exposure correction factor as well as a safety factor must be considered.

TABLE 7. HUMAN RESPIRATORY TIDAL VOLUMES

	Body weight, kg	Experimental conditions	Minute volume, liters/min
Newborn	3.4 (2.5-4.3)		0.584 (0.471-0.697)
Adult, male	68.5		7.43 (5.8-10.3)
		light work	28.6 (27.3-30.9)
		heavy work	42.0 (39.3-45.2)
Adult, female	54.0		4.5 (4.0-5.1)
		light work	16.3 (15.9-16.8)
		heavy work	24.5 (17.3-31.8)

Adapted from Handbook of Environmental Control, Vol. I, Table 2.1-15 entitled Respiratory Frequency, Tidal Volume, and Minute Volume: Vertebrates[18]

A Monsanto Corporation report[19] originally suggested a simple model for relating TLV's to permissible ambient concentrations. Their model is described by Equation 1; it incorporates an exposure correlation (relating 8-hour workroom exposure to 24-hour continuous exposure) and an arbitrary safety factor of 100.

$$\mathrm{EPC}\ (\mathrm{mg/m^3}) = 0.01 \times 8/24 \times \mathrm{TLV}\ (\mathrm{mg/m^3}) = \mathrm{TLV}/300 \qquad (1)$$

Handy and Schindler[20] noted that TLV's consider weekend recovery time for workers (exposure is for 5 of 7 days) and by modifying the exposure correction suggested by Monsanto, arrived at the model described by Equation 2 appropriate for continuous ambient exposure. This model is utilized in the MEG's methodology to establish EPC_{AH1} (equations 3 and 4).

$$EPC\ (mg/m^3) = 0.01 \times 40/168 \times TLV\ (mg/m^3) = TLV/420 \qquad (2)$$

Therefore:

$$EPC_{AH1}\ (\mu g/m^3) = 10^3 \times TLV\ (mg/m^3)/420 \qquad (3)$$

and,

$$EPC_{AH1a}\ (ppm) = TLV\ (ppm)/420 \qquad (4)$$

Example: TLV for ammonia = 18 mg/m^3 (25 ppm)

$$EPC_{AH1} = 10^3 \times 18/420 = 43\ \mu g/m^3$$

$$EPC_{AH1a} = 25/420 = 0.06\ ppm$$

NIOSH criteria documents detailing the NIOSH occupational exposure recommendations are currently available for approximately 70 chemical substances. Specific numerical recommendations by NIOSH are substituted for TLV's in the model for deriving EPC_{AH1} if (1) TLV is not established, or (2) if the NIOSH recommendation is lower than the established TLV.

As a corollary to the Monsanto/Handy and Schindler TLV model, a model to define EPC's for simple asphyxiants may also be described. Simple asphyxiants are inert gases or vapors which do not produce physiologic effects except when they are present to the extent of limiting available oxygen or when present in quantities sufficient to result in an explosion hazard. The only compound classified as a simple asphyxiant for which ACGIH has specified a TLV is carbon dioxide, CO_2; this TLV is based on the concentration of CO_2 which lowers the available oxygen level below acceptable levels. In order to describe EPC's for other simple asphyxiants, the assumption is made that a similar concentration of any other simple asphyxiant will likewise lower oxygen levels below acceptable levels since the phenomenon involved is a physical rather than a chemical effect. Based on this assumption, TLV_{SA} is defined as 5,000 ppm, analogous to the TLV established for CO_2. Substituting TLV_{SA} for TLV in the Equation 4 allows calculation of EPC's in ppm for all asphyxiants. Concentrations expressed in ppm are readily converted to $\mu g/m^3$ by Equation 5.

$$\mu g/m^3 = 10^3 \times \text{molecular wt.} \times \text{ppm}/24.5 \qquad (5)$$

Example:

Ethane, C_2H_6, is a gas classified as a simple asphyxiant.
TLV for ethane has not been established by the ACGIH.
$TLV_{SA} = 5,000$ ppm.
$EPC_{AH1a} = 5,000/420 = 11.9$ ppm.
Molecular wt. for $C_2H_6 = 30$.

Therefore,

$$EPC_{AH1} = 10^3 \times 30 \times 11.9/24.5 = 14,600\ \mu g/m^3$$

5.2.1.1.2 Model deriving EPC_{AH2} from LD_{50} (oral, rat) -- In the absence of TLV's a reasonable source of empirical data relevant to estimating permissible concentrations of substances is animal toxicity data. Such data is available for many more chemical substances than are currently addressed by TLV's. The most extensive readily available source of animal toxicity data is the Registry of Toxic Effects of Chemical Substances published by the National Institute of Occupational Safety and Health (NIOSH).[12] The 1976 Registry contains information on 21,729 different chemical substances. Routes of administration, species of animals tested, dosages, and toxic effects are included.

While the relationship between animal toxicity and human health has not been clearly defined, toxicological assessments depend largely on animal experimentation as an indication of relative toxicities of chemical substances. Any evaluation concerning permissible exposure levels must consider animal toxicity. Both NIOSH and ACGIH base their recommendations for contaminant levels in workroom atmosphere on experimental animal studies, as well as on industrial experience and data derived from experiments on humans.

LD_{50} (defined as the calculated dose of a chemical substance which is expected to cause the death of 50 percent of an entire population of an experimental animal species as determined from exposure to the substance) is the most consistently reported animal toxicity datum. LD_{50}'s are normally expressed in mg of toxicant per kg of animal body weight.

Because LD_{50} values are most often determined for rats, dosage administered orally, these values provide the experimental data base for application in alternate models for describing toxicity based EPC's when TLV's are not available.

Handy and Schindler[20] have plotted TLV's for 241 substances against the corresponding LD_{50} (oral, rat) values in an effort to describe a relationship between the animal data and contaminant levels permissible for human exposure in workroom environments. Using a regression technique, a correlation between TLV and LD_{50} (oral, rat) is discernable, although the data scatter is sufficient to limit confidence. To produce an acceptably reliable and conservative number, Handy and Schindler have defined a term which they call TLV_{LOW} that they relate to the lower 95 percent confidence limit associated with the regression correlation. This term is defined by Equation 6:

$$TLV_{LOW}\ (mg/m^3) = 4.5 \times 10^{-4} LD_{50}\ (mg/kg) \quad (6)$$

Adjusting the TLV_{LOW} for continuous exposure using the factor 40/168, Handy and Schindler describe a maximum permissible concentration defined by Equation 7:

$$Xp\ (mg/m^3) = 1.07 \times 10^{-4}\ LD_{50}\ (mg/kg) \quad (7)$$

This equation is incorporated into the MEG's methodology to provide a model for translating LD_{50} (oral, rat) into EPC's for air based on health effects:

$$EPC_{AH2}\ (\mu g/m^3) = 0.107\ LD_{50}\ (mg/kg)$$

Example: 2,4-Dichlorophenol

No TLV established; LD_{50} (oral, rat): 580 mg/kg

$$EPC_{AH2} = 0.107 \times 580 = 62\ \mu g/m^3$$

5.2.1.1.3 Model deriving EPC_{AH3} from LD_{50} (oral, rat) -- On the basis of assumptions derived from data provided by Piotrowski,[21] a second model for relating LD_{50}'s to maximum permissible air concentrations is also described by Handy and Schindler.[20] This model considers (1) accumulation of a specific pollutant within the body, and (2) the body burden which does not affect health. They assume a 30-day biological half-life and a safe limit for maximum body concentration of 0.05 percent of the LD_{50} for a chemical substance. Equation 9 results from this Handy and Schindler[20] model.

$$Xp\ (mg/m^3) = 8.1 \times 10^{-5}\ LD_{50}\ (mg/kg) \tag{9}$$

where Xp is the maximum permissible concentration in mg/m^3.

This model expressed in $\mu g/m^3$ is incorporated into the MEG's methodology as shown in Equation 10.

$$EPC_{AH3}\ (\mu g/m^3) = 0.081\ LD_{50}\ (mg/kg) \tag{10}$$

Example:

2,4-Dichlorophenol

No TLV established; LD_{50} (oral, rat): 580 mg/kg

$$EPC_{AH3} = 0.081 \times 580 = 47\ \mu g/m^3$$

If LD_{50} (oral, rat) is not available, other animal toxicity data reported, such as LD_{50} (oral, mouse) or LD_{Lo} (intraperitoneal, mouse), are substituted in Equations 8 and 10. LD_{50} (oral, mouse) is the first preferred substitute; in other cases judgments as exercised in selecting the datum to be substituted for LD_{50} (oral, rat). For example, if LD_{50} (oral, rat) were not reported, but LD_{Lo} (oral, rat), LD_{50} (oral, mouse), and LD_{50} (intraperitoneal, rat) were available, the value judged to be most indicative of LD_{50} (oral, rat) is used.

EPC's calculated using Equations 8 and 10 should be expected to be lower than respective EPC's derived from Equation 3 because of the conservative nature of the models translating LD_{50}'s.

An attempt was made to correlate LC_{50} (Lethal Concentration to 50 percent of population) with TLV's. However, due to the scarcity of LC_{50} information, only LD_{50}'s have been included as basic data for model development. Occasionally, only an LC_{50} is reported for highly volatile substances. In these cases, an LD_{50} based on the LC_{50} is derived, taking into consideration breathing rate and duration of exposure. Such derivations are presented in the Background Information Summaries.

5.2.1.2 EPC's for Air Based on Ecological Effects

Toxicity based estimated permissible concentrations based on ecological effects are derived from the lowest reported concentration having an effect on a common plant indigenous to the U.S. The species indicated to be most sensitive to a given pollutant and the nature of the effect are indicated in the Background Information Summaries.

It is assumed that a plant's response to an air contaminant is dose-related. Because data are reported for various exposure durations, an exposure time correction to 24 hours is required. All exposures are normalized to reflect a 24-hour exposure duration. For example, to correct a 3-hour exposure to a 24-hour exposure, multiply the reported concentration by 3/24. A safety factor of 0.1 is applied to the corrected dosage to describe EPC_{AE}:

$$EPC_{AE}\ (\mu g/m^3) = 0.1 \times \text{lowest reported effective dose}\ (\mu g/m^3) \qquad (11)$$

Example: Ethylene

Molecular wt: 28; 0.001 ppm is reported to cause leaf epinasty in African marigold (1-day exposure).

$$EPC_{AE} = (0.001)(0.1) = 0.0001\ \text{ppm}$$

$$\frac{(0.0001\ \text{ppm})(28)}{24.5} = 0.114\ \mu g/m^3$$

5.2.2 Toxicity Based EPC's for Water

EPC's for water have been specified on the bases of human health effects and on ecological effects.

5.2.2.1 EPC's for Water Based on Health Effects

Two models for describing EPC's for water based on health effects are included in the MEG's methodology.

5.2.2.1.1 Model deriving EPC_{WH1} from EPC_{AH} -- EPC_{WH1} is based on the EPC for air reported in the MEG chart under the general heading "Toxicity Based Estimated Permissible Concentration" (column A). The model is a simplified version of one first proposed by Stokinger and Woodward.[22] Assumptions made in deriving EPC_{WH1} for a given compound from its EPC_{AH} are:

1) The average respiratory tidal volume for adults is 30 m^3 air per 24 hours. (Refer to Table 7 for representative tidal volumes for humans).

2) Drinking water consumption averages 2 liters daily/person.

3) The entire contaminant loading in the 24-hour tidal volume is absorbed through the lungs into the body. This is a conservative assumption representing the worst case situation. In fact, absorption of compounds through the lungs varies with chemical species, and estimated factors range from 0.1 to 1. Table 8 lists estimated absorption factors for inhalation and ingestion for several previously studied chemical substances.

4) Daily absorption (through inhalation or through ingestion) of the entire contaminant loading in 30 m^3 of air containing the estimated permissible concentration of a contaminant does not result in a dosage exceeding a safe level. This assumes that a contaminant is metabolized or excreted at a rate which precludes accumulation beyond a safe body burden.

The permissible daily contaminant loading in μg is calculated as follows:

$$\text{permissible contaminant } \mu g/\text{day} = (30\ m^3/\text{day})(\text{EPC } \mu g/m^3) \qquad (12)$$

An estimated permissible water concentration EPC_{WH1} can then be described by equation 13.

$$EPC_{H1}\ (\mu g/\ell) = \frac{\text{permissible contaminant } (\mu g/\text{day})}{\text{drinking water consumed } (\ell/\text{day})} = \frac{30\ (m^3) EPC_{AH}\ (\mu g/m^3)}{2\ (\ell)} \qquad (13)$$

$$= 15\ EPC_{AH}$$

Example: n-Butanol

$EPC_{AH1} = 357\ \mu g/m^3$

$EPC_{WH1} = 15 \times 357 = 5,355\ \mu g/\ell)$

TABLE 8. COMPARATIVE ABSORPTION FACTORS FOR SELECTED CHEMICAL SUBSTANCES

Organic Compound	Absorption Factor	
	Inhalation	Ingestion
Acetone	0.5	1.0
Acrylonitrile	0.75	0.85
Allyl alcohol	0.75	0.8
Aniline	0.5	1.0
Benzene	0.35	0.4
Carbon tetrachloride	0.3	0.5
Ethylenediamine	0.75	0.8
Formaldehyde	0.8	0.8
Methyl bromide	0.3	0.5
Methylchloroform	0.1	0.5
Phenol	1.0	1.0
Pyridine	0.1	0.5

*All figures approximate.
Adapted from Stokinger and Woodward, Toxicological Methods for Establishing Drinking Water Standards; from Journal of the American Water Works Association, V. 515, 1958.

5.2.2.1.2 Model deriving EPC_{WH2} from TLV or LD_{50} -- A second model for translating LD_{50}'s and TLV's into maximum permissible water concentrations is attributed to Handy and Schindler[20] and takes into consideration (1) safe maximum body concentration; and (2) biological half-life of a chemical contaminant. For this model a half-life of 30 days was assumed and a safe maximum body concentration equal to 0.05 percent of the LD_{50} was used. Equations 14 and 15 below describe the Handy and Schindler models which incorporate these assumptions:

$$x_E = 1.38 \times 10^{-2}\ \text{TLV; TLV known and estimated; } \tau \leq 30\text{d} \qquad (14)$$

$$x_E = 4.0 \times 10^{-4} LD_{50}\text{; } LD_{50}\text{ known and estimated; } \tau \leq 30\text{d} \qquad (15)$$

where: x_E is maximum permissible concentration in mg/ℓ and τ is the biological half-life.

These equations with units changed are incorporated into the MEG's methodology to calculate EPC_{WH2}:

$$EPC_{WH2}(\mu g/\ell) = 13.8 \times TLV \qquad (16)$$

or,

$$EPC_{WH2}\ (\mu g/\ell) = 0.4\ LD_{50}\ \text{(used if TLV not established)} \qquad (17)$$

NIOSH recommendations if more stringent than the TLV's are substituted in Equation 16.

Examples: Biphenyl: TLV = 1 mg/m^3

$EPC_{WH2} = 13.8 \times 1 = 13.8\ \mu g/\ell$

Benzaldehyde: TLV not established;

LD_{50} (oral, rat) = 1300 mg/kg

$EPC_{WH2} = 0.4 \times 1{,}300 = 520\ \mu g/\ell$

5.2.2.2 EPC's for Water Based on Ecological Effects

The MEG's methodology incorporates four models for establishing EPC's for water based on ecological effects (ecological effects in this application may be lethal, sublethal, or cumulative effects in aquatic species or aquatic ecosystems).

It is recognized that certain substances are nutrients required by aquatic species. However, no attempt is made in this report to define minimum permissible levels.

5.2.2.2.1 Model deriving EPC_{WE1} based on LC_{50} -- EPC_{WE1} is derived from a model which requires an application factor and the lowest reported LC_{50} or TLm for a given substance. LC_{50} or TLm designate the calculated concentration of a contaminant expected to cause death in 50 percent of an experimental aquatic population. TLm is most commonly reported for a 96-hour test duration and is expressed as TLm-96-hr. An application factor describes the ratio between the safe and the lethal concentration of a given contaminant under specified conditions. Application factors generally vary from approximately 0.01 to 0.1. However, the number of application factors determined experimentally is limited because of the problems involved in establishing a safe concentration level; such determinations involve growth and reproduction studies of long duration and excessive cost.

Since application factors have not been established for most of the chemical substances for which TLm's are reported, a model incorporating an assumed application factor is used into the MEG's methodology.

The following system described in the NAS/NAE Water Quality Criteria 1972[9] provides a reasonable basis for estimating permissible water concentrations for aquatic life.

1) For nonpersistent toxicants, (half-life <4 days) an application factor of 0.05 will be applied to the 96-hour LC_{50}.

2) For persistent or cumulative toxicants (half-life $\geq$ 4 days) an application factor of 0.01 should be applied to the 96-hour LC_{50}.

Equation 18 below is used to calculate EPC_{WE1}. The application factor assumes a nonpersistent toxicant.

$$EPC_{WE1}\ (\mu g/\ell) = 50 \times \text{lowest reported TLm}\ (mg/\ell) \qquad (18)$$

Example: Acetic acid: TLm 96: 100 - 10 ppm

$$EPC_{WE1} = 50 \times 10 = 500\ \mu g/\ell$$

5.2.2.2.2 Model for deriving EPC_{WE2} based on fish tainting levels -- EPC_{WE2} describes a contaminant level in water which will not result in tainting of fish flesh. Tainting is evident as objectionable taste, odor, or color occurring in exposed aquatic species. The lowest reported contaminant level to produce such an effect is reflected in EPC_{WE2}:

$$EPC_{WE2}\ (\mu g/\ell) = \text{lowest concentration reported to cause tainting}\ (\mu g/\ell) \qquad (19)$$

Example: Naphthalene: Concentrations of 1 mg/ℓ are reported to cause tainting of fish flesh.

$$EPC_{WE_2} = 1{,}000\ \mu g/\ell$$

5.2.2.2.3 Model for deriving EPC_{WE3} based on information provided in Water Quality Criteria -- EPC_{WE3} is the lower value derived from either of two models requiring data which are provided in the various recognized Water Quality Criteria documents. This EPC is calculated only when the appropriate criteria do not define a safe or minimal risk concentration for aquatic life. EPC_{WE3} is determined from Equations 20 or 21 which follow:

$$EPC_{WE3}\ (\mu g/\ell) = \text{Application Factor} \times \text{lowest Tlm}\ (\mu g/\ell) \qquad (20)$$

where: application factor is specified in recognized Criteria

or,

$$EPC_{WE3}\ (\mu g/\ell) = \text{Hazard Level}\ (\mu g/\ell) \times 0.2 \qquad (21)$$

where: hazard level is specified in recognized Criteria.

The factor 0.2 in Equation 21 is derived from the ratio of minimal risk level to hazard level which results most frequently in the Criteria when both levels are specified for a given contaminant.

Example: Antimony: 96-hr. LC_{50} is equivalent to 67 ppm, as Sb; NAS/NAE Water Quality Criteria, 1972: For marine life--hazard level: 0.2 mg/ℓ; application factor: 0.02 (to be applied to the 96-hour LC_{50}).

EPC_{WE3} 0.02 × 67,000 = 1,340 μg/ℓ

or,

EPC_{WE3} = 200 × 0.2 = 40 μg/ℓ

The lower value, 40 μg/ℓ, appears on the MEG chart.

5.2.2.2.4 Model for deriving EPC_{WE4} based on cumulative factors -- EPC_{WE4} is derived from a model which incorporates (1) the reported concentration factor for a given chemical substance, and (2) maximum allowable concentration of that contaminant in fish flesh. Concentration factors are defined as the ratio of the ultimate concentration of a contaminant which may be accumulated in an organism to the concentration of the contaminant in the water supporting the organism. Equation 22 below is used to calculate EPC_{WE4}:

$$EPC_{WE4} = \frac{\text{maximum allowable concentration } (\mu g/kg)}{\text{concentration factor}} \tag{22}$$

Example: Alkyl Mercury (as Hg) -- Bioaccumulation of mercury (in fish) from water may be as high as 10,000 times: The Food and Drug Administration sets a limit for maximum allowable concentration of mercury in edible portions of fish at 0.5 μg/g (500 μg/kg).

EPC_{WE4} = 500/10,000 = 0.05 μg/ℓ

5.2.3 Toxicity Based EPC's for Land

Two types of models have been considered in establishing a primary MEG's methodology for relating empirical data to EPC's for soil contaminants, although only one of these has been applied to the toxicants addressed in this report. The second concept remains to be developed further before substantial numbers of calculations can be made.

5.2.3.1 EPC's for Land Based on Health Effects

Human health effects are very difficult to relate to toxicant levels in land since human absorption of such toxicants directly from soils is unlikely to be significant. (An exception to this generalization is one incident of lead poisoning in a child due to soil ingestion , although data from a study of lead burdens in children living in high soil lead areas suggest that ingested soil lead is "a relatively unimportant source of lead for children.")[23] It is reasonable to assume, however, that excessive levels of contaminants in soils may influence contaminant levels in other media from which humans are more apt to absorb the contaminant. Such media include:

1) ambient air,
2) drinking or recreation water contaminated via leachate processes,
3) crops for human consumption grown in contaminated soil and affected by uptake of specific contaminants, and
4) meat from livestock affected either by high contaminant levels in soils where they are raised or by excessive contaminant levels in feed resulting from soil uptake of toxicants.

Of these media likely to be influenced by soil contaminants, water affected by leachate is the medium most easily addressed by a broadly applicable model concept, such a model is included in the MEG's methodology. A model to couple crop uptake of a contaminant with its maximum acceptable concentration in food might also be of value in relating human health effects to EPC's for soil if the assumptions required for such a model could be properly justified.

5.2.3.1.1 Model for deriving EPC_{LH} based on worst case leaching -- A model relating acceptable contaminant levels in water to acceptable contaminant levels in soil is predicated on a worst-case assumption that two liters (2 kg) of water is sufficient to leach 100 percent of a given toxicant from one kilogram of soil. By equating the resulting contaminant concentration in the two liters of water with the EPC_{WH} for the specific contaminant of interest, EPC_{LH} may be derived. Equation 23 below is used to describe the EPC_{LH} in appropriate units:

$$EPC_{LH}\ (\mu g/g) = 0.002 \times EPC_{WH}\ (\mu g/\ell) \qquad (23)$$

where: EPC_{WH} is the concentration for water appearing in the the MEG chart in column A under the general heading "Toxicity Based Estimated Permissible Concentrations."

Example: Toluene: $EPC_{WH1} = 13{,}400\ \mu g/\ell$

$EPC_{WH2} = 5{,}200\ \mu g/\ell$

(EPC_{WH2} value appears on MEG's chart)

$EPC_{LH} = 0.002 \times 5{,}200 = 10.4\ \mu g/g$

5.2.3.1.2 Concept for model deriving EPC_{LH} based on crop uptake -- Crop uptake describes the process whereby contaminants in soil are transmitted to crops grown in that soil. Several researchers have studied the extent of contaminant uptake for certain heavy metals (particularly cadmium) under varying soil conditions and for several plant species. However, because of the many variables which apparently influence the transfer process (soil type, pH, species, etc.), general conclusions have not been reached relating contaminant levels in soils to the resulting concentrations in crops.[16]

A model for deriving soil EPC's based on crop uptake can be set forth provided (1) the assumption is made that 100 percent of a contaminant is absorbed from a given volume of soil by the total crop yield produced by that amount of soil, and (2) that it is possible to establish a maximum safe concentration of a contaminant in food crops. (The U. S. Food and Drug Administration, as well as the Food and Agriculture Organization of the United Nations in conjunction with the World Health Organization, have recommended maximum acceptable concentration levels of certain heavy metals in food. FDA continues to monitor food sources for these contaminants and others, including PCB's and certain pesticides, in a continuous effort to evaluate safe contaminant levels.)[24]

In the absence of FDA or WHO recommendations, a maximum safe concentration of a given contaminant in food crops may be described by Equation 24. (The logic used in developing the equation is similar to that required for deriving EPC_{WH1} in Section 5.2.2.1.1):

$$(\mu g/g) = \left[\frac{30\ (m^3/\text{person-day}) \times EPC_{AH}\ (\mu g/m^3)}{\text{quantity of food (g/person-day)}}\right] \quad (24)$$

(Maximum Safe Contaminant Concentration (MSC) in Food-Crop)

If y grams of food crop are produced from z grams of soil, and if the allowable contaminant concentration in the crop is MSC, assuming 100 percent contaminant uptake by the crop allows an EPC for land to be derived as follows:

$$EPC_{soil}\ (\mu g/g) = \frac{\text{Total mass of contaminants } (\mu g/g) \text{ in soil required to produce y grams of food crop}}{\text{z (g of soil)}} \quad (25)$$

and,

Total mass of contaminant = MSC ($\mu g/g$) × y (g) ($\mu g/g$) in z grams of soil (26)

Substituting (26) into (25) yields:

$$EPC_{soil}\ (\mu g/g) = \frac{MSC\ (\mu g/g) \times y\ (g)}{z(g)} \quad (27)$$

Substituting (24) into (27):

$$EPC_{soil}\ (\mu g/g) = \frac{\left(\frac{30 \times EPC_{AH}}{\text{quantity of food (g/person-day)}}\right) \times \text{(y grams of food)}}{\text{(z grams of soil)}} \quad (28)$$

The model just described does not consider the slow rate of contaminant uptake. It describes crop uptake in a worst-case batch situation rather than as a perpetual (or certainly long-lived) phenomenon. [It might be added that if a rapid uptake crop could be developed, it might serve as a valuable means for reclaiming certain heavy metal contaminants from solid waste].

Alternatively, a model may be adapted to assume that crops take up all initially present soil contaminants over a period of time, say, twenty years. The initial mass of contaminant would then be distributed (although not evenly) during this time through a mass of food-crop substantially greater than the mass of the soil that supported it. Since MSC is constant (as described in Equation 24), the resulting EPC_{soil} would be much higher than is implied in Equation 27 since the ratio y/z would be large.

Resulting contaminant levels in crops for most situations are low compared to contaminant concentrations in the supporting soil; it is possible, however, for a plant to take up contaminants selectively, thereby concentrating a particular contaminant within its mass. At the other extreme, uptake may be nil, indicating the crop's selective rejection of the contaminant.

In view of the problems associated with generalizing about crop uptake (specifically, the unpredictable behavior of most chemical species in addition to oversimplification of the uptake phenomenon in the model), calculations of EPC's for land on the basis of crop uptake have been omitted in this MEG's report. Discussion of the model is included merely as "food for thought" in an effort to provide incentive for more in-depth research in the area of crop uptake as a basis for EPC's for land.

5.2.3.2 EPC's for Land Based on Ecological Effects

A model for calculating EPC's for land based on indirect effects to the ecology parallels the leachate model described in Section 5.2.3.1.1 for deriving EPC_{LH}. The model is expressed in Equation 29 below:

$$EPC_{LE}\ (\mu g/g) = 0.002 \times EPC_{WE}\ (\mu g/\ell) \qquad (29)$$

Where: EPC_{WE} is the concentration for water appearing on the MEG chart in column B under the general heading "Toxicity Based Estimated Permissible Concentrations".)

Example: Acetic acid: $EPC_{WE1} = 500\ \mu g/\ell$

$$EPC_{LE} = 0.002 \times 500 = 1\ \mu g/g$$

Unlike toxic human health effects, ecological effects are likely to result directly, as well as indirectly, from contaminants in soil. Examples of direct effects to the ecology include phytotoxic effects, poisoning of foraging animals due to frequent ingestion of large quantities of soil, and effects in soil microorganisms. Empirical data referable to soil concentrations, although sparce, have been included in the background information summaries for MEG's for some contaminants. However, models for translating such data into EPC's for soil have not been incorporated into the MEG's methodology thus far because of the scarcity of readily available data and because primary emphasis was placed on other aspects of the MEG's.

5.3 ESTIMATED PERMISSIBLE CONCENTRATIONS FOR ZERO THRESHOLD POLLUTANTS

"Zero threshold pollutant" is a term used commonly in the industrial hygiene and toxicology fields to denote known or suspected genotoxins*. Genotoxin, as used in this report, refers to chemical substances that affect genes including carcinogens, mutagens, and some teratogons.

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*The term genotoxin has been used by Dr. Eugene Sawicki of EPA/HERL in an IARC publication. It was probably coined by H. Druckery, a German oncologist.

Substances which have produced carcinogenic or neoplastic responses in experimental animals or in humans are termed oncogenic. Carcinogenic refers to compounds which produce or tend to produce cancer. The term neoplastic is related to the growth or development of tumors which are benign, potentially malignant, or malignant. A teratogenic compound induces structural and/or functional deviation in the process of embryogenesis. The effects of teratogens are observed in the offspring of the individual animal exposed. Mutagenesis results in a permanent change in hereditary material involving a physical change in chromosome relations or a fundamental change in genes.

The concept of "thresholds" is based on the premise that there exists some defineable concentration, below which a chemical will not produce a toxic response in an exposed subject. Thresholds, as explained by Stokinger[25] and by Bingham,[26] signify a nonlinear relationship between dose and response at the initiation of the response. The solid line in Figure 3 illustrates the dose response relationship implied by threshold dosage; the dotted line represents the zero threshold concept. The existence of thresholds for genotoxins has been a widely debated question that is still unanswered, although, highly convincing arguments have been made for

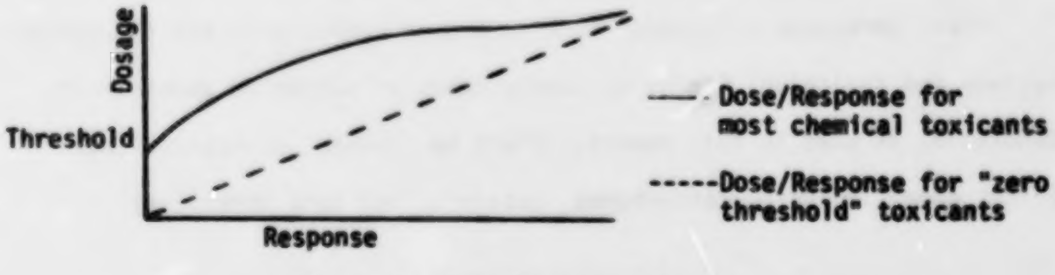

Figure 3. Dose/Response Curves.

the "occurrence of biologically significant intracellular molecular interactivity."[27] It is primarily the lower end of the dose/response curve that is elusive since dose/response patterns for high dosages of active genotoxins can often be established experimentally (for example, by comparing dosage levels with numbers of tumors produced).

The term "zero threshold pollutants" is used within the MEG's methodology to signify those types of compounds, specifically genotoxins, for which thresholds may or may not exist. In using this term we do not wish to imply that we have chosen sides in the threshold concept debate. Estimated permissible concentrations for genotoxins are intended here to indicate estimated acceptable risk levels rather than established safe concentrations. Acceptable levels for genotoxins, although not directly relatable to safe concentrations, need to be defined (or at least estimated) so that such compounds may be viewed within the same frame of reference as other toxicants. Meaningful priorities among hazardous environmental contaminants can only be established if the entire array of pollutants (including genotoxins as well as other toxicants) can be surveyed and referenced to levels that are expected to be permissible concentrations. ACGIH, in referring to occupational exposure to certain suspect carcinogens, has recommended "no exposure or contact by any route." OSHA, in setting standards for 16 recognized carcinogens, has prescribed special precautions to prevent occupational exposure to the substances; acceptable levels, however, are not described in the standards. Since the activity levels for suspect carcinogens varies widely, "no exposure" designations are not practical for extrapolation to the entire range of suspect carcinogens and therefore are not adaptable for use in MEG's methodology.

The most recent evidence linking dosage levels to incidence of tumors in experimental animals substantiates the premise that carcinogens differ greatly in their potency. The activities of particular suspect carcinogens have been shown to vary with dosages, higher dosage levels resulting in higher incidences of tumors affected within shorter incubation times. It has also been noted that when diverse carcinogens are administered at the same dosage, they may initiate markedly different frequencies of response, especially at lower dose levels.[28]

In view of these findings, the need is clear for a system to allow ranking of various compounds in terms of their relative genotoxic potential as a first step in estimating acceptable risk concentrations. The obvious basis for a ranking system is the available empirical information from epidemiological or experimental animal studies such as the data collected in the NIOSH Suspected Carcinogens List, A Subfile of the Toxic Substances List.[29] (The latest update of this data is not consolidated yet in a subfile and remains a part of the NIOSH Registry of Toxic Effects of Chemical Substances.)[12]

Although it is believed that teratogenesis and oncogenesis are dosage related effects like other toxic effects, LD_{50}'s are not indicative of carcinogenic or teratogenic properties of compounds. Carcinogenic or neoplastic responses are not necessarily lethal and do not show up in acute toxicity studies. Teratogenic effects of a toxicant are not indicated in the animal exposed since the effect is only observed in the offspring. Attempts to correlate data relative to permissible concentrations and genotoxicity has led to the development of EPC's based on a scheme involving the lowest dosage resulting in an oncogenic or teratogenic response. Teratogenesis and oncogenesis are considered independently in this scheme.

The models developed to translate available data into EPC's based on genotoxicity incorporate a variety of assumptions and arbitrary factors and weighting schemes. The models appear to generate reasonable numbers, however, and the method is broadly applicable to suspected carcinogens and teratogens. It is recognized that the models are highly simplistic, and it is expected that current research into mechanisms of carcinogenesis will provide the basis for more refined models in the future. Appendix G of this report provides a very brief overview of concepts relative to carcinogenesis which might influence later versions of the MEG's methodology.

5.3.1 Zero Threshold Pollutants: EPC's for Air

A system developed by EPA's Office of Toxic Substances for ordering suspected carcinogens and suspected teratogens has been modified to enhance its use in the MEG's methodology. The modified ordering system allows ranking of genotoxins and is used as the basis for a model to derive numerical EPC's for air for a wide array of suspected carcinogens. A model which makes use of the few numerical TLV's or NIOSH recommendations that recognize carcinogenic potential is also employed for those compounds addressed by such recommendations.

Where both EPC_{AC1} and EPC_{AC2} may be calculated, the lower value is entered in the MEG chart as the air EPC under Zero Threshold Pollutants.

5.3.1.1 Model Deriving EPC_{AC1} from TLV's or NIOSH Recommendations that Recognize Carcinogenic Potential of the Substances Addressed

EPC_{AC1} is patterned after the model described in Section 5.2.1.1.1 for calculating EPC_{AH1} based on TLV's or NIOSH recommendations.

Appendix A of the ACGIH TLV list[17] is devoted to carcinogens, and substances addressed in this Appendix are designated as either "Human Carcinogens" or "Industrial Substances Suspect of Carcinogenic Potential in Man;" numerical TLV's have been assigned to some of the substances listed. These TLV's which recognize carcinogenic potential are used as the basis for a model for calculating EPC_{AC1} in the same way that TLV's for non-suspect carcinogens are used in the model for calculating EPC_{AH1}. Also, as in EPC_{AH1} calculations, NIOSH recommendations which recognize carcinogenic potential may substitute for TLV's in calculating EPC_{AC1}. Equation 30 is used:

$$EPC_{AC1}\ (\mu g/m^3) = 10^3 \times \text{TLV or NIOSH recommendation recognizing oncogenic potential } (mg/m^3) \Big/ 420 \qquad (30)$$

Example: Beryllium: The TLV for beryllium is 0.002 mg/m^3 and recognizes beryllium as an "Industrial Substance Suspect of Carcinogenic Potential for Man."

$$EPC_{AC1} = 10^3 \times 0.002/420 = 0.005\ \mu g/m^3$$

5.3.1.2 Model Deriving EPC_{AC2} from Adjusted Ordering Numbers

EPC_{AC2} is derived from a model which translates "adjusted ordering numbers," based on a ranking system for suspected carcinogens, into permissible air concentrations. They system for establishing adjusted ordering numbers is a refinement of an ordering plan developed by EPA's Office of Toxic Substances presented in An Ordering of the NIOSH Suspected Carcinogens List Based Only on Data Contained in the List.[30] EPA's ordering plan resulted in the assignment of four digit ordering numbers (hereafter referred to as EPA/NIOSH ordering numbers) for all those substances entered in the NIOSH Suspected Carcinogens List. The numbers assigned in the EPA plan are an "indication of the relative degree of concern that might be warranted for a particular substance regarding its possible carcinogenic potential." It is not appropriate, however, to conclude that all the substances which are assigned numbers are carcinogenic.

The derivation of EPA/NIOSH ordering numbers follows:

First digit -- The number corresponding to the highest priority species giving a response is assigned as the first digit of the ordering number. Priorities are delineated below:

Species (in order of priority)	*Number*
Human	*7*
Monkey	*6*
Cat, dog, pig, cattle, or domestic animal	*5*
Rat	*4*
Mouse	*3*
Guinea pig, gerbil, hamster, rabbit, squirrel, or unspecified mammal	*2*
Bird, chicken, duck, turkey	*1*
Frog	*0*

Second digit -- The number of different species reported to have developed tumors as a result of exposure determines the second digit of the ordering number. (The highest number that can be entered is 9).

Third digit -- The third digit is designated 0, 1, or 2 according to the most significant route of administration eliciting an oncogenic response. Various routes of administration and the corresponding digit assignment are:

Inhalation, occular, or skin application	*2*
Oral Administration	*1*
All other routes	*0*

The highest number applicable is assigned.

Fourth digit -- The total number of species/route combinations reported is entered as the fourth digit of the ordering number. (The highest number that can be entered is 9.)

An example of the ordering number derivation for Dibenz (a,h)-anthracene is discussed below. The total entry for Dibenz (a,h) anthracene (except references) from the NIOSH Registry of Toxic Effects of Chemical Substances is presented in Table 9. A key to abbreviations in the entry is included for the convenience of those not familiar with the Toxic Substances List.

The first digit of the EPA/NIOSH ordering number for Dibenz (a,h)-anthracene will be 4, since rat is the highest priority species in which a carcinogenic response is reported. Oncogenicity has been demonstrated in five different species. Thus the second digit of the ordering number is 5. The third digit is 2, since the data indicate that one route of administration affecting an oncogenic response is skin application. Since 9 species/route combinations are reported, the fourth digit of the ordering numher is 9. The complete four-digit EPA/NIOSH ordering number therefore is 4529.

It should be pointed out that in laboratory animal testing of suspected carcinogens, experiments are most often first carried out on

TABLE 9.12 ENTRY FROM THE NIOSH REGISTRY FOR (DIBENZO(a,h) ANTHRACENE)

```
BN26250. DIBENZ(a,h)ANTHRACENE
         CAS:  000053703    MW: 278.36          MOLFM: C22-H14
         WLN: L G6 D6 B666J
         SYN: DB(a,h)A   *  1,2,5,6-DIBENZANTHRACENE      1,2:5,6-DIBENZANTHRACENE *
              1,2,7,8-DIBENZANTHRACENE   *  DIBENZO(a,h)ANTHRACENE  *
         TXDS: scu-rat TDLo:500 μg/kg TFX:Car
               orl-mus TDLo:360 mg/kg/22WC TFX:CAR
               skn-mus TDLo:6 μg/kg TFX:NEO
               scu-mus TDLo:76 μg/kg TFX:CAR
               ivn-mus LDLo:10 mg/kg
               ivn-mus TDLo:10 mg/kg TFX:CAR
               imp-mus TDLo:80 mg/kg TFX:NEO
               scu-gpg TDLo:16 mg/kg/82W TFX:CAR
               ims-pgn TDLo:11 mg/kg TFX:CAR
               irn-frg TDLo:8 mg/kg TFX:CAR
```

Key to abbreviations used in Registry entry.

CAS	Chemical Abstracts Service Registry Number
MW	molecular weight
MOLFM	molecular formula
WLN	Wiswesser Line Notation
SYN	synonyms
TXDS	qualifying toxic dose
TDLo	lowest published toxic dose
TFX	toxic effects
CAR	carcinogenic effects
NEO	neoplastic effects
W	week
C	continuous
scu	subcutaneous
orl	oral
skn	skin
ivn	intravenous
imp	implant
ims	intramuscular
irn	intrarenal
mus	mouse
gpg	guinea pig
pgn	pigeon

mice or on rats. Subsequent experiments to obtain more precise information for substances demonstrated to be active carcinogens may be conducted using rats, mice, or other species including higher animals and employing alternate routes of exposure. Since testing of higher animals is very expensive and usually requires long testing periods, such tests are conducted only when the results are likely to provide data not obtainable from rodent testing. Chemicals producing tumors in rats and mice at very low dosages will probably be tested in higher animals in an attempt to determine target organs in species more closely related to man. Also, substances believed to be carcinogenic to man but which do not produce tumors in rodents will probably be tested in higher mammals whose metabolic functions more closely parallel human functions. The high weighting factor in the EPA/NIOSH ordering number associated with priority species tested appears valid, considering the pattern that is generally followed in the testing of a chemical carcinogen.

The EPA/NIOSH ordering numbers have been modified in the MEG's methodology to incorporate effective dosages in indicating carcinogenic potential of chemical substances. As described above, the EPA/NIOSH ordering number successfully incorporates information related to animals and routes of administration with arbitrary, but carefully considered weighting given to each item. However, no consideration has been given in such ordering numbers to effective dosages required. By incorporating lowest effective dosages, the reliability of the system for ranking suspected carcinogens is strengthened.

Lowest Effective Dosages are determined through bioassay procedures. When positive results are obtained for a substance administered at a moderate or high dosage, additional testing is generally conducted at different dose levels. Experiments often involve two or more dose ranges administered to different groups of animals as well as the appropriate positive, negative, and vehicle controls.

Dosages to be used in carcinogen bioassays are generally very carefully selected in planning an experiment. High dosages (but tolerable for test duration survival) are generally used in carcinogen bioassay so that a positive result is evident within a short time. A balance is required, however, and maximum tolerated dose (selected on the basis of mortality and weight gain in short term tests) is the primary factor in selecting the dose to be administered in the bioassay. On the basis of maximum tolerated bioassay dose for oral administration, generally a chemical should not comprise more than 5 percent of the diet, and 2-3 percent is probably adequate to detect even a weak carcinogen.[28]

EPA/NIOSH ordering numbers have thus been modified to dosage-adjusted ordering numbers, hereafter referred to as "adjusted ordering numbers." Equation 31 describes the modified ordering numbers.

$$\text{Adjusted ordering number} = \frac{\text{EPA/NIOSH ordering number}}{\text{Lowest dosage resulting in an oncogenic response (mg/kg)}} \qquad (31)$$

Dividing the EPA/NIOSH ordering number by the lowest TD_{Lo} reported to produce an oncogenic response magnifies differences between compounds tested in similar species and expands the range of numbers associated with the full array of suspected carcinogens, while at the same time incorporating additional highly pertinent information into the data base for the ranking numbers.

Adjusted ordering numbers determined for substances addressed in this report range from <0.1 to >3,000,000. Very large adjusted ordering numbers indicate that a small dosage was required to affect the response. On the other hand, a small number indicates a high dosage was required. Thus, adjusted ordering numbers increase with the expected potency of a chemical carcinogen.

Adjusted ordering numbers can be determined for any substance for which information is available regarding (1) species responding to the carcinogen; (2) effective routes of administration; and (3) lowest effective dosages. The adjusted ordering number for a suspect carcinogen is determined as follows (refer to Table 9 and discussion of EPA/NIOSH ordering numbers):

Dibenz(a,h) anthracene: EPA/NIOSH ordering number = 4529;
Lowest TD_{Lo} eliciting an oncogenic response is 6 $\mu g/m^3$ (0.006 mg/m^3)
Adjusted ordering number = 4529/0.006 = 754,833

Such a high number indicates that there is a high hazard potential associated with this compound. In an effort to distinguish the more hazardous carcinogens, substances with adjusted ordering numbers lower than 1.0 will generally not be treated as suspected carcinogens in the calculation of EPC's as part of the MEG's methodology.

The idea of eliminating (by dosages required to elicit tumors) certain substances from the list of suspect carcinogens is not unique to the MEG's methodology. ACGIH in the intended changes presented as Appendix A to the 1976 TLV's[17] specifies that no substance is to be considered an occupational carcinogen of practical significance if it requires effective dosages exceeding certain prescribed maximum dosages. These dosages are listed in Table 10.

TABLE 10. MAXIMUM EFFECTIVE DOSES ALLOWED FOR CHEMICAL SUBSTANCES TO BE CONSIDERED OCCUPATIONAL CARCINOGENS BY ACGIH

Route	Species	Maximum Dose
Respiratory	mouse	1,000 mg/m^3
	rat	2,000 mg/m^3
Dermal	mouse	1,500 mg/kg
	rat	3,000 mg/kg
gastrointestinal	mouse	10 g
	rat	100 g
	Other	500 mg/kg/day for lifetime

Adjusted ordering numbers do not reflect numbers of tumors produced in animals or the organs affected. This information, although valuable, need not be incorporated directly into a ranking scheme if it can be assumed that any compound reported to produce a carcinogenic or neoplastic effect in an animal has been tested with proper controls so that the reported oncogenic effects are significant and not merely representative of normal background tumor incidence. (Such an assumption is probably optimistic, but is nevertheless acceptable for developing the methodology here.)

The adjusted ordering numbers just described provide an effective system for ranking genotoxins. Furthermore, it may be assumed that EPC's for suspected carcinogens and teratogens will be inversely proportional to such ordering numbers:

$$EPC_{carcinogen} = \frac{K}{\text{adjusted ordering number}} \tag{32}$$

K for model EPC_{AC2} is arbitrarily assigned a value of 1/6 in order to establish EPC's lower than 1 nanogram for the most potent carcinogens. Thus Equation 33 is used to calculate EPC_{AC2}.

$$EPC_{AC2}\ (\mu g/m^3) = \frac{10^3}{6 \times \text{adjusted ordering number}} \tag{33}$$

The value of 1 nanogram has been equated with the "lowest concentration of concern" by Handy and Schindler[20] as a result of their investigation into permissible concentrations of carcinogenic polynuclear aromatic hydrocarbons found in cigarette smoke. They suggest this concentration as a "reasonable permissible" concentration for establishing control technology R&D priorities.

In seeking a value for K, an additional criteria was that EPC's based on adjusted odering numbers should correlate with EPC's based on TLV or NIOSH recommendations which recognize carcinogenic potential. The value

1/6 satisfies the criterion reasonably well. Table 11 lists EPC_{AC1} and EPC_{AC2} for those substances addressed by MEG's in this report for which adjusted ordering numbers as well as TLV's which recognize carcinogenic potential are available. The average ratio of EPC_{AC1} to EPC_{AC2} is 1.25 if the value for beryllium is rejected. (The adjusted ordering number is $>1.6 \times 10^7$ for beryllium making the EPC_{AC2} far below the 1 nanogram level).

Adjusted ordering numbers and corresponding values of EPC_{AC2} for compounds addressed by MEG's in this report are listed in Table 12. Compounds are listed in order of increasing EPC_{AC2}.

TABLE 11. COMPARISON OF EPC_{AC1} AND EPC_{AC2}

Substance	EPC_{AC1}	EPC_{AC2}	EPC_{AC1}/EPC_{AC2}
Lithium	14.6	11.4*	1.28
Beryllium	0.05	0.00001	500***
Hydrazine	0.36	15.7	0.02
Nickel	0.03	0.3	0.01
Nickel Carbonyl	0.1	6.4	0.01
Cadmium	0.12	0.02	6
Chromium	0.002	0.02	0.01

*Adjusted
**Value not averaged due to extremely low EPC_{AC2}.

TABLE 12. TABLULATION OF ADJUSTED ORDERING NUMBERS AND EPC_{AC2} VALUES FOR SUBSTANCES ADDRESSED BY MEG's

Category No.	Substance	Adjusted Ordering No.	EPC_{AC2}
32	Beryllium	16,000,000	0.00001
21	Benzo(a)pyrene	3,314,500	0.00005
21	Dibenz(a,h)anthracene	754,833	0.0002
21	7,12-Dimethylbenz(a)anthracene	272,809	0.0006
12	N-Nitrosodimethylamine	59,053	0.003
22	3-Methylcholanthrene	18,683	0.009
82	Cadmium	7,329	0.02
68	Chromium	7,327	0.02
54	Selenium	6,426	0.03
11	N,N'Dimethylhydrazine	2,208	0.075
74	Cobalt	1,682	0.1
21	Dibenz(a,i)pyrene	1,612	0.1
21	Benz(a)anthracene	1,562	0.11
23C	Dibenz(c,g)carbazole	679	0.24
10C	Aminotoluenes	638	0.26
12	N-Nitrosodiethylamine	577	0.29
76	Nickel	477	0.3
10C	2-Aminonaphthalene	423	0.4
23B	Dibenz(a,h)acridine	312.4	0.53
23B	Dibenz(a,j)acridine	284	0.59
10B	Ethylenimine	210.6	0.8
46	Lead	136	1
10C	1-Aminonaphthalene	124	1.3
71	Diazomethane	78	2
22	Benzo(b)fluoranthene	78	2.1
21	Dibenzo(a,l)pyrene	64.6	2.6
10C	4-Aminobiphenyl	54	3
17	4-Nitrobiphenyl	54	3
21	Phenanthrene	44	3.8
21	Indeno(1,2,3-cd)pyrene	43	3.9
7A	Formaldehyde	42.7	3.9
21	Methyl chrysenes	39	4.3
26A	Tetraethyl lead	36	4.6
11	p-Dimethylaminoazobenzene	35	5
21	Chrysene	31.5	5.3
21	Picene	28	6
76	Nickel carbonyl	26	6.4
21	Benzo(e)pyrene	23	7.25
26B	Nickelocene	20.2	8
26C	Copper 8-hydroxyquinoline	20	8.3
21	Dibenzo(a,h)pyrene	18.9	8.8
23C	Dibenzo(a,g)carbazole	11.6	14
22	Benzo(j)fluoranthene	10.8	15.4
47	Hydrazine	10.6	15.7
83	Mercury	10.5	16
19	2,4-Dichlorophenol	10	17
21	Dibenz(a,c)anthracene	7.1	23.5
23B	Benz(c)acridine	6.67	25
23C	Indole	6.5	26

TABLE 12. (continued)

Category No.	Substance	Adjusted Ordering No.	EPC_{AC2}
23C	Dibenz(a,i)carbazole	6	28
6B	1-Chloro-2,3-epoxypropane	4.3	39
8D	Phthalate esters	4.3	39
21	Benzo(g)chrysene	4.3	39
10C	Benzidine	3.5	48
23B	Dibenz(c,h)acridine	3.06	54.5
21	Benzo(c)phenanthrene	2.5	66.7
16B	α-Chlorotoluene	1.9	88
79	Silver	1.7	98
21	Anthracene	1.3	133
21	Naphthalene	1.2	142
11	Monomethylhydrazine	1	167
21	Pyrene	0.3	556

5.3.1.3 Model Deriving EPC_{AT} from Adjusted Ordering Numbers

Compounds which have demonstrated teratogenic activity may be assigned ordering numbers and adjusted ordering numbers in the same manner described for potentially oncogenic substances.

EPC_{AT} is derived from a model which translates "adjusted ordering numbers," based on a ranking system for teratogenic potential, into permissible air concentrations. Thus, EPC_{AT} (equation 34) is identical to EPC_{AC2} except that the adjusted ordering number is based on teratogenic potential.

$$EPC_{AT}\ (\mu g/m^3) = \frac{10^3}{6 \times \text{adjusted ordering number}} \qquad (34)$$

5.3.2 Zero Threshold Pollutants: EPC's for Water

EPC's for carcinogenic and teratogenic substances in water are derived from very similar models. Both EPC_{WC} and EPC_{WT} are based on EPC's for air for a given substance.

5.3.2.1 Model Deriving EPC_{WC} from EPC_{AC}

EPC_{WC} is based on the EPC_{AC}, by adjusting for the daily per capita breathing volume (30 m^3) and water intake (2 ℓ). Assuming the amount of contaminant permissible from air exposure is also permissible in drinking water, the following equation relates EPC_{WC} and EPC_{AC}:

$$EPC_{WC}(\mu g/\ell) = 15 \times EPC_{AC}\ (\mu g/m^3) \qquad (35)$$

The EPC's for water, therefore, are based on TLV's that recognize the carcinogenic potential of substances and adjusted ordering numbers for carcinogenic substances.

5.3.2.2 Model Deriving EPC_{WT} from EPC_{AT}

EPC_{WT} is derived from EPC_{AT}, adjusting for the daily per capita breathing volume (30 m^3) and water intake (2 ℓ). Assuming the amount of contaminant permissible from air exposure is also permissible in drinking water, the following equation relates EPC_{WT} and EPC_{AT}:

$$EPC_{WT}\ (\mu g/\ell) = 15 \times EPC_{AT}\ (\mu g/m^3) \qquad (36)$$

5.3.3 Zero Threshold Pollutants: EPC's for Land

Land EPC's for carcinogenic and teratogenic substances are derived from similar models. EPC_{LC} and EPC_{LT} are based on EPC's for water for a given substance.

5.3.3.1 Model Deriving EPC_{LC} from EPC_{WC}

EPC_{LC} is based on potential carcinogenic effects resulting from water contamination through leaching of chemical substances from soil. The model based on worst case leaching is described in Section 5.2.3.1.1. Equation 37 is used to calculate EPC_{LC}.

$$EPC_{LC}\ (\mu g/g) = 0.002 \times EPC_{WC}\ (\mu g/\ell) \qquad (37)$$

5.3.3.2 Model Deriving EPC_{LT} from EPC_{WT}

EPC_{LT} is based on teratogenic effects resulting from water contamination through leaching of chemical substances from soil. The model is analogous to that used for deriving EPC_{LC}. Equation 38 is used.

$$EPC_{LT}(\mu g/g) = 0.002 \times EPC_{WT}\ (\mu g/\ell) \qquad (38)$$

5.4 CONCLUSIONS

A few general comments are required to permit some perspective into the methodology. First, all of the modelling schemes require that certain assumptions be made, and a worst case approach has been taken to keep the MEG values conservative. In some instances, arbitrary constants are incorporated in an effort to correlate the various sets of EPC's. Efforts have been made to incorporate judgements of others relative to the levels of pollutants safely tolerated by human beings. In this regard, heavy reliance in the methodology has been placed on TLV's established by the American Conference of Governmental Industrial Hygienists (ACGIH). Models to generate EPC's for land need further attention. A mechanism for incorporating more detailed information into the models used for calculating EPC's for genotoxins should be devised.

The methodology defines a total of 22 different kinds of EPC's, many of them interrelated (EPC's for water, for example, may be derived from EPC's for air). Although multiple EPC's are calculated on the background information summaries, only the most stringent EPC for a given media/criteria combination will appear on the MEG chart for a given substance.

SECTION 6

EMISSION LEVEL GOALS

Emission Level Goals are desirable levels of contaminants in point source or fugitive emissions. Discharge streams addressed by Emission Level Goals may be gaseous, aqueous, or solid in nature. Emission level Goals for chemical contaminants may be described on the basis of technology factors or ambient factors.

Technology Based Emission Level Goals have not been addressed by the methodology presented in this report, hence the remainder of the discussions in this section will focus on Emission Level Goals based on ambient factors. Technology based Emission Level Goals will be the subject of a future report. Certain Emission Level Goals have been established by Federal promulgations under EPA's New Stationary Source Performance Standards[31] and Effluent Guidelines and Standards.[32] These regulations are based on technological considerations that are source specific, however, and extrapolation of these regulations to general application is not valid.

Five specific criteria for Emission Level Goals based on ambient factors have been included in the MEG's methodology. These are (1) minimum acute toxicity effluents (MATE's) based on human health effects; (2) MATE's based on ecological effects; (3) estimated permissible concentrations (EPC's) based on human health effects; (4) EPC's based on ecological effects; and (5) concentrations representing elimination of discharge (EOD).

Emission Level Goals based on MATE concentrations are generated via a system of models as described in Section 6.1. In addition to addressing specific chemical substances MATE's, for certain "totals" have also been considered to describe effluent ceiling levels for selected substances that might be measured in combination. MATE values for "totals" are highly relevant to environmental assessment programs and are to be used in conjunction with MATE's for specific contaminants. (MATE's for specific components of complex effluents are described without regard to potential complications associated with the concurrent presence of several pollutants.)

Emission Level Goals based on EPC's reflect Ambient Level Goals discussed in the previous section. Dilution factors (source specific values relating emission concentrations at the point of discharge to the resulting maximum ambient concentrations) are applied to the Ambient Level Goals to describe desirable emission concentrations. Dilution factors have been determined for a variety of emission situations and a conservative range appears to be between 10 and 1,000. A discussion of dilution factors and the conditions affecting their magnitude is presented in Section 6.2.

EOD concentrations are natural background concentrations multiplied by appropriate dilution factors. These values represent the most stringent Emission Level Goals. Natural background concentrations are levels of contaminants measured in rural locations (pristine areas isolated from highly populated centers). Section 6.3 discusses the EOD goals and the conventions adopted for providing these numerical values in the MEG's chart.

The top half of the MEG's chart has been designed to array technology based goals and ambient factor goals based on the five criteria. The values appearing on the chart will generally become progressively more stringent from left to right since technology based goals are generally expected to be less stringent than goals based on ambient factors. MATE values describe contaminant levels higher than EPC's. EPC's are, for the most part, higher than natural background concentrations.

6.1 MINIMUM ACUTE TOXICITY EFFLUENTS (MATE'S)

MATE's describe very approximate concentrations for contaminants in source emissions to air, water, or land which will not evoke significant harmful or irreversible responses in exposed humans or ecology, when those exposures are limited to short duration (less than 8 hours per day). Six specific MATE concentrations may be specified for most chemical substances, since effects to humans and to the ecology are considered separately in each of the three media. (MATE's for land are, of course, not relevant to contaminants that are gases under normal conditions.) MATE values are intended to serve both as relative hazard indicators and as estimated absolute indicators of levels of contaminants in effluents that will prevent serious acute toxic effects. As such, the values should serve a useful purpose for those involved in environmental assessment by furnishing emission level goals that may be referred to potential environmental hazard levels and ultimately to control technology goals.

A methodology has been developed for deriving MATE values through a system of models which uses several different types of available information relating to properties of chemical toxicants. These models closely parallel those discussed in Section 5 for generating EPC's. Data utilized in the MATE's methodology are collected from the following sources:

- Threshold Limit Values (TLV's) -- established by the American Conference of Governmental Industrialist Hygienists (ACGIH) to describe levels of contaminants permissible in workroom air.
- National Institute for Occupational Safety and Health (NIOSH) recommendations -- maximum concentrations for workroom atmosphere.
- Drinking Water Regulations
- Water Quality Criteria
- Radiation Regulations
- Lethal and toxic dose information from animal studies and from human exposures. Such data are provided in the NIOSH Registry of Toxic Effects of Chemical Substances, 1976 Edition;[12] Patty's Industrial Hygiene and Toxicology;[5] Dangerous Properties of Industiral Materials by Sax;[6] the IARC Monographs of Evaluation of Carcinogenic Risk[8]; and other sources. Types of data reported are:

  LD_{50} -- *dosage resulting in death (lethal dose) for 50 percent of the animal population tested, expressed as mg/kg of animal.*

  LD_{Lo} -- *lowest lethal dose reported for a species/route combination.*

  LC_{50} -- *lethal concentration to 50 percent of the animals tested.*

  TD_{Lo} -- *lowest dosage reported to result in a specified response (for example, a carcinogenic response).*

  TLm -- *threshold limit median, i.e., lethal concentration to 50 percent of aquatic population exposed.*

  LC_{Lo} -- *lowest lethal concentration reported.*

  TC_{Lo} -- *lowest toxic concentration reported to result in a specified response.*

While most of the MATE values are derived from information relevant to acute toxic effects, evidence of carcinogenesis or teratogenesis has been utilized as well. It has been shown that such responses, although not immediate acute effects, may result from a short-term or single dose exposure, making such data extremely relevant to MATE value determinations.

The methodology developed for calculating MATE's (illustrated in Figure 4) emphasizes a modeling approach that translates data of diverse types and origins into multimedia effluent concentrations that are of comparable hazard potential. The magnitude of a MATE for a substance is inversely related to the potential hazard of the substance. Thus, a ranking of substances according to MATE values allows comparison of the relative potential hazards of those substances. To aid in comparison of MATE's, the values are uniformly recorded in $\mu g/m^3$ (or ppm) for air, in $\mu g/\ell$ for water, and in $\mu g/g$ for land. The methodology developed to generate MATE values produces a reasonable index for immediate use and a point of departure for refining the system to incorporate more sophisticated models. MATE's corresponding to TLV's and NIOSH recommendations provide reliable absolute indicators of minimum acute toxicity concentrations, although specific MATE values derived from other sources have not been subjected to thorough evaluation.

An effort has been made to tabulate at least preliminary MATE's for all the entries on the Master List, even though data collection is substantial only for 216 substances. (See Appendix C.) It must be emphasized

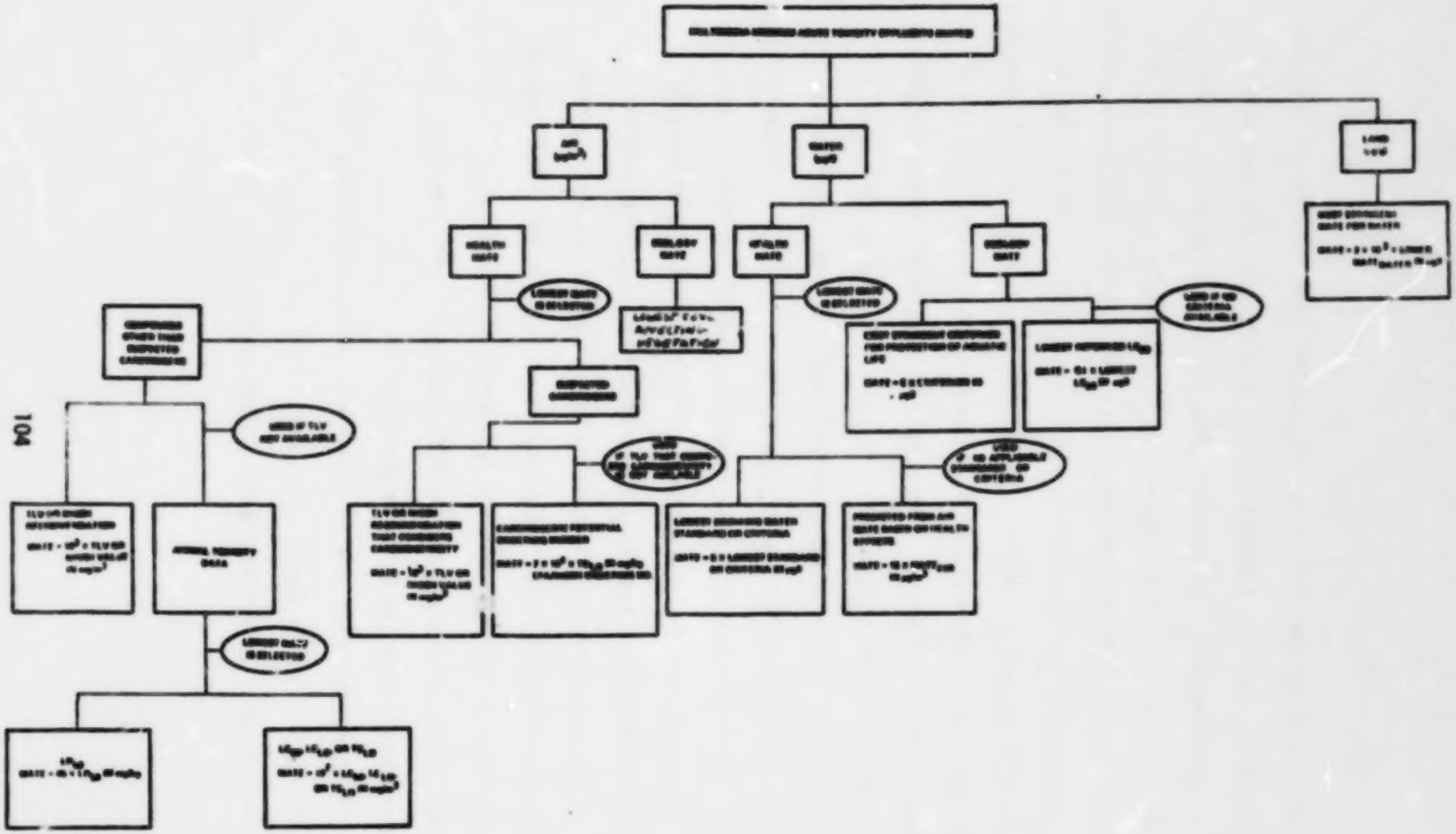

Figure 4. Methodology for Deriving MATE's from Empirical Data.

that MATE's for compounds or elements other than those addressed by background information summaries and MEG charts (see Appendix E) are based on extremely limited research and are subject to revision. It is certain that many of the "N" designations in the tabulations in Appendix C will be eventually replaced by appropriate numbers and that errors in the tabulations will become apparent as a result of research required for preparation of the first MEG's supplement.

The most stringent MATE's for those substances addressed by MEG's charts in this report are calculated on the Background Information Summaries, and the values are entered on the MEG charts in the appropriate columns under Emission Level Goals.

6.1.1 MATE's for Air Based on Health Effects

For compounds addressed by a Threshold Limit Value (TLV) and/or NIOSH recommendation, the MATE for air based on health effects corresponds to the TLV or to the NIOSH recommendation, if lower. TLV concentration levels are time-weighted averages assuming that a worker will be exposed for 8 or 10 hours per day and 40 hours per week. The time-weighted averages are not intended to specify fine lines between safe and dangerous conditions. TLV's are based on evidence of acute and chronic effects to humans (including carcinogenic or suspected carcinogenic effects) and on studies of animal toxicity (acute, chronic, and oncogenic effects).

$$\text{MATE}_{\text{AH1}}\ (\mu g/m^3) = 10^3 \times \text{TLV or NIOSH recommendation}\ (mg/m^3) \qquad (39)$$

$$\text{MATE}_{\text{AH1a}}(\text{ppm}) = \frac{24.5 \times 10^3}{\text{molecular wt.}} \times \text{TLV or NIOSH recommendation (mg/m}^3) \quad (40)$$

$$\text{MATE}_{\text{AC1}}\ (\mu\text{g/m}^3) = 10^3 \times \text{TLV* or NIOSH recommendation* (mg/m}^3) \quad (41)$$

MATE's for compounds not addressed by a TLV or NIOSH recommendation are based on animal toxicity data employing the relationship between TLV's and LD_{50}'s established by Handy and Schinder. (See discussion in Section 5.2.1.1.2.)

Handy and Schindler have compared TLV's with LD_{50}'s (oral, rat or most closely related value) defining a quantity which they call TLV_{low} which represents the lower 95 percent confidence limit for the TLV/LD_{50} relationship. The TLV_{low} represents a time-weighted average concentration and is defined by the following equation:

$$TLV_{low}\ (\text{mg/m}^3) = 4.5 \times 10^{-4}\ LD_{50}\ (\text{mg/kg}) \quad (42)$$

Assuming that the TLV_{low} incorporates an average safety factor of 100, and changing the units to $\mu g/m^3$, a MATE based only on animal toxicity data may be specified using Equation 43.

$$\text{MATE}_{\text{AH2}}\ (\mu\text{g/m}^3) = 100 \times TLV_{low}\ (\mu\text{g/m}^3) = 45 \times LD_{50}\ (\text{mg/kg}) \quad (43)$$

If the oral LD_{50} for rat is not reported, the most closely related LD_{50} or LD_{Lo} is substituted. For example, oral LD_{Lo} for rat, oral LD_{50} or LD_{Lo} for mouse, or intravenous LD_{50} or LD_{Lo} for rat may be used.

*carcinogenicity considered

Results of inhalation studies in humans or in animals are available for certain compounds. This information, expressed as LC_{50}, LC_{Lo}, or TC_{Lo}, may be used as the basis for MATE concentrations for compounds addressed by a TLV or NIOSH recommendation. LC_{50}, LC_{Lo}, and TC_{Lo} values are generally expressed in mg/m³ or in ppm. Equation 44 will be used to calculate MATE's from inhalation data.

$$MATE_{AH3}\ (\mu g/m^3) = 100 \times LC_{50},\ LC_{Lo},\ \text{or}\ TC_{Lo}\ (mg/m^3) \qquad (44)$$

In cases where inhalation data as well as LD_{50} data are available, both air MATE's are calculated, and the lower value is entered in the tabulations.

In addition to lethal and toxic efffects indicated by LD_{50}, LC_{50}, and TC_{Lo} values, it is also reasonable to consider as a basis for MATE's the ability of a compound to induce tumors. Compounds that have produced tumors in animals are designated suspected carcinogens. Although some people subscribe to the theory that there is no threshold level for carcinogens, many toxicologists and oncologists believe that carcinogenesis is a dosage related effect. According to the International Agency for Research on Cancer, dose-response studies are important in the evaluation of human and animal carcinogenesis:

> *The confidence with which a carcinogenic effect can be established is strengthened by the observation of an increasing incidence of neoplasms with increasing exposure. In addition, such studies form the only basis on which a minimal effect dose can be established, allowing some comparison with data for human exposure.*[33]

Laboratory animal studies have demonstrated that a high proportion of treated animals will develop tumors within a few months if exposed to certain potent carcinogens.

In the absence of established TLV's or NIOSH recommendations recognizing potential carcinogenicity, MATE concentrations for suspected carcinogens are based on adjusted ordering numbers (discussed in Section 5.3.1.2) and hence consider route of administration, animal species known to be affected, and lowest effective dosage.

MATE's for suspected carcinogens are calculated according to Equation 45 and may be considered to reflect the carcinogenic potential associated with a given compound based on data presently available. The concentrations obtained from Equation 45 agree reasonably well with TLV's established for suspected carcinogens. The MATE which reflects the carcinogenic potential of a compound is included in the tabulations if the value is lower than the MATE calculated by other equations or if other data were unavailable.

$$\text{MATE}_{\text{AC2}}\ (\mu\text{g/m}^3) = \frac{7 \times 10^4}{\text{adjusted ordering number}} \qquad (45)$$

MATE's calculated by Equation 45 are not tabulated if they exceed $7 \times 10^4\ \mu\text{g/m}^3$.

For compounds addressed by TLV's or NIOSH recommendations which take into consideration the carcinogenic potential of a compound, MATE's entered in the tabulations will be calculated according to Equation 41.

MATE's for known or suspected teratogens are also calculated according to Equation 45 using the adjusted ordering number which reflects the teratogenic potential associated with a given compound.

6.1.2 MATE's for Air Based on Ecological Effects

The minimum concentration of a contaminant in an air emission which will not adversely affect vegetation (exposure of limited duration) is expressed by Equation 46.

$$\mathrm{MATE}_{AE}(\mu g/m^3) = \text{lowest concentration (corrected to 24 hour exposure) reported to produce effects in vegetation } (\mu g/m^3) \quad (46)$$

6.1.3 MATE's for Water Based on Health Effects

Health based MATE's for water are derived from drinking water standards or criteria for those compounds addressed by existing standards or criteria. Only the lowest prescribed value for a compound or element is used in the calculation of MATE. Standards and criteria surveyed include National Interim Primary Drinking Water Regulations,[34] Public Health Service Drinking Water Regulations,[35] NAS/NAE 1972 Water Quality Criteria, Public Supplies,[9] and EPA 1976 Quality Criteria for Water (Domestic Supplies).[14] The MATE concentrations are calculated as follows:

$$\mathrm{MATE}_{WHS}\ (\mu g/\ell) = 5 \times \text{Lowest Standard or Criteria } (\mu g/\ell) \quad (47)$$

The multiplier of 5 was chosen arbitrarily and is probably conservative. In choosing the multiplier, consideration was given to long biological half-lives, severity of effects, and dosages known to cause effects for compounds addressed by drinking water regulations.

For those compounds not addressed by drinking water standards or criteria, MATE's for water are predicted on the basis of the tabulated air MATE based on health effects. The air and water MATE's are related according to Equation 48.

$$\mathrm{MATE}_{WH1}(\mu g/\ell) = 15 \times \mathrm{MATE}_{AH}\ (\mu g/m^3) \quad (48)$$

Equation 48 was suggested by the approach used by Stokinger and Woodward[22] and later by Handy and Schinder[20] in relating air concentrations to water concentrations (see Section 5.2.2.1.1 for explanation of this model).

Since only the lowest calculated MATE's for air are included in the tabulations, the MATE's for water are based on the most conservative air MATE's. Indirectly, the bases for the water MATE's for compounds not addressed by drinking water standards are TLV's, LD_{50}'s, LC_{50}'s, TC_{Lo}'s or TD_{Lo}'s and ordering numbers.

6.1.4 MATE's for Water Based on Ecological Effects

Ecology based MATE's for water reflect criteria recommended for the protection of aquatic life by NAS/NAE in Water Quality Criteria 1972[9] or by EPA in 1976 Quality Criteria for Water.[14] MATE's are calculated according to Equation 49 for those chemical substances addressed by established criteria.

$$MATE_{WES}\ (\mu g/\ell) = 5 \times \text{Most Stringent Criteria}\ (\mu g/\ell) \qquad (49)$$

The multiplier 5 in Equation 49 is suggested by the relation between minimal risk levels and hazard levels for aquatic life as recommended by the NAS/NAE.[9] Both hazard levels and minimal risk levels are recommended for 22 substances. The estimated hazard level is most often between 2 and 5 times the recommended minimal risk concentration for continuous exposure. Since MATE concentrations are for short term exposure, 5 times the minimal risk level will describe concentrations somewhat below the hazard level.

For those compounds not addressed by established criteria for protection of aquatic life, MATE's are based on the lowest LC_{50} reported. Equation 50 is used to describe MATE's based on LC_{50}'s.

$$MATE_{WE1}\ (\mu g/\ell) = 100 \times \text{Lowest } LC_{50}\ (mg/\ell) \tag{50}$$

Application factors (ratios of safe to lethal concentrations) have been established for many substances and range from 0.01 to 0.1. Since MATE's apply to short term rather than continuous exposure, the factor 0.1, is applied to the LC_{50} (mg/ℓ). Converting the units from mg/ℓ to μg/ℓ, the constant multiplier finally becomes 100.

6.1.5 MATE's for Solid Waste Based on Health Effects

Health based MATE's for solid waste are estimated concentrations of contaminants in solid waste (whether disposed to land or to water) which will not affect human health as a result of direct or indirect exposure of limited duration.

The MATE value for a given contaminant in solid waste is based on the more stringent MATE for water tabulated for that compound. It is assumed that toxicants in 1,000 grams of waste may be leached entirely by two liters of water. Therefore, the mass of contaminant allowable in 1,000 grams must not exceed the contaminant allowable in two liters of water. One liter of water is equivalent to 1,000 grams. Equation 51 is used.

$$MATE_{LH1}\ (\mu g/g) = 0.002 \times MATE_{WH}\ (\mu g/\ell) \tag{51}$$

This means that the MATE's$_{LH1}$ are indirectly based on TLV's, LD$_{50}$'s, LD$_{Lo}$'s, LC$_{50}$'s, TL$_{Lo}$'s, ordering numbers and TD$_{Lo}$'s, drinking water standards or criteria, water quality criteria for protection of aquatic life, or LC$_{50}$ for aquatic life.

6.1.6 MATE's for Solid Waste Based on Ecological Effects

A solid waste MATE value based on ecological effects is generated from the water-ecology MATE value for a given compound.

The leaching model described previously is again utilized. Equation 52 is used to calculate the MATE.

$$\text{MATE}_{LE1}\ (\mu g/g) = 0.002 \times \text{MATE}_{WE}\ (\mu g/\ell) \qquad (52)$$

This means that MATE$_{LE1}$ is indirectly based on LC$_{50}$, TLm, or Federal Water Quality Criteria.

6.1.7 Limitations to the Methodology

It should be emphasized that the MATE concentrations derived through this methodology are based on empirical data presently available in general secondary references. Time limitations preclude a thorough search of the literature pertinent to each specific compound. It is certain that many of the values will be eventually revised, especially as data gaps are filled. In light of the general nature of the references used, some qualifications should be made regarding the reliability of the MATE values in the tabulations included in Appendix C.

1) TLV's and NIOSH recommendations represent opinions of highly trained toxicologists and industrial hygienists. Their judgments regarding safe levels for workroom contaminants, however, are

not infallible; ACGIH has made its intention clear that the TLV's are to be used only in the practice of industrial hygiene and that it does not recommend their use as a relative index of hazard or toxicity.[17]

2) Information reported in the NIOSH Registry of Toxic Effects of Chemical Substances[12] has been used extensively in calculating MATE's. NIOSH, in compiling the Registry, has made no attempt to report the numbers of animals tested, quantity or site of tumors produced in carcinogenicity studies, or precise conditions under which the data were obtained. The level of confidence to be associated with toxicity data such as LD_{50}'s, LD_{Lo}'s, TD_{Lo}'s, LC_{50}'s, or LC_{Lo}'s is heavily dependent on this information. It follows that the level of confidence to be associated with MATE's based on information from the NIOSH Registry is also imprecise.

3) LD_{50}'s may vary widely for a given compound in relation to species, sex, and age of the animals tested, the route of administration of the toxicant, and other test conditions. Because they are available for most compounds, oral LD_{50}'s have been employed rather than LD_{50}'s derived from other routes of administration. While this procedure allows for consistency in the calculations, obvious complications involved in the use of oral LD_{50}'s arise e.g., differences in the oral absorption factors among the various chemical substances.

4) LC_{50}'s or TLm's for aquatic life reported in the NIOSH Registry[12] as well as in other sources indicate lethal concentrations of toxicants for a specific laboratory test procedure. The numbers are greatly dependent on conditions of the test: species of aquatic life monitored: static or flow-through conditions; temperature; pH; and the presence of additional toxicants. The lowest LC_{50}'s reported in the data base underlying this report were used in the calculations of ecology-based MATE's for water. Extension of the data base will probably yield additional, possibly lower LC_{50}'s representing more sensitive species.

5) No consideration has been given to additive effects from simultaneous exposure through different media, in addition, synergistic and/or antagonistic effects have been ignored in describing MATE values.

6) It is recognized that carcinogens react biologically in a number of different ways, and the incidence of synergisms, cocarcinogenicity, promotion, and metabolic alterations into more or less active metabolites cannot be resolved in the scheme employed here for describing MATE's for suspected carcinogens.

Many of the values are based on limited toxicological data and rely on models in series for relating various effective dosages to minimum acute toxicity concentrations. Models used to derive water concentrations from air concentrations assume a worst case situation and may prove overly conservative in some cases, as may the values extrapolated through the solid waste model from MATE water concentrations. In addition, certain of the application factors used are arbitrary.

MATE's for substances not addressed specifically by either TLV's or available toxicity data are in some cases based on data pertinent to a related substance or group of compounds (i.e., having a common parent element). In these cases, appropriate adjustments for molecular weight are made, or where the parent element is of most concern, this will be indicated. For example, the air, health MATE's for all antimony compounds (except antimony trioxide) are 500 $\mu g/m^3$, as Sb, based on the TLV for antimony and antimony compounds, as Sb. The MATE for antimony trioxide has a different basis because of its association with cancer.

While the limitations described above must be emphasized, benefits from the preliminary tabulation of Minimum Acute Toxicity Effluents may still be realized by those involved with environmental assessment. The methodology developed here should provide preliminary decision criteria for emerging systems from other projects exploring methodologies for environmental assessment. At the very least, the concept of MATE's and the tabulations presented in Appendix C should generate further comments on possible applications for the system, as well as suggestions for refining the models used to calculate MATE's.

6.1.8 MATE's for Totals

MATE values for specific chemical contaminants, although valuable, are not sufficient to characterize an environmentally acceptable emission stream. Ceiling values for certain "Totals" associated with gaseous, aqueous, or solid waste emissions are also required. Such Totals are to be used in conjunction with the MATE's for specific chemical contaminants and provide a secondary check for effluent contaminant levels.

Selection criteria for Totals are:

1) The parameter must be related to the presence of more than one species.

2) The parameter must be federally regulated in some context. Federal guidelines surveyed for possible totals to be addressed include NAAQS, NSPS, effluent guidelines, drinking water standards, water quality criteria.

3) The parameter is measurable by some established method.

The following parameters are classified as Totals to be addressed by MATE's. Ultimately, a MATE value will be specified for each Total listed. MATE values for the land Totals may be based on water MATE Totals via a leaching model.

Air	Water	Land
Total hydrocarbons	Total Suspended solids;	Total leachable organics
Total particulates		Total leachable substances
	Total dissolved solids; Total organic carbon (TOC)	
	Biological oxygen demand (BOD)	
	Chemical oxygen demand (COD)	

Algorithms designed to generate EPC's and MATE's for specific chemical contaminants are not applicable to Totals. Instead, attention must be given to each parameter in order to recommend a MATE value.

Values for Totals will be recommended with consideration given to: (1) existing regulations and recommendations; (2) associated toxicity; (3) dilution factors expected at the site of dispersion of the effluent; and (4) the nature of the environmental problems associated with the substances indicated by the Total.

Recommendations for air Totals along with background information are presented on pages 117 - 120 as examples of the approach conceived to describe Total MATE values.

6.2 EMISSION LEVEL GOALS BASED ON AMBIENT LEVEL GOALS

Emission Level Goals more stringent than the MATE's are derived from Ambient Level Goals (i.e., EPC's). Ambient Level Goals, as discussed in Section 5, are presented in the lower half of the MEG's chart. The most stringent values for each medium, based on health and based on ecological effects, are then entered on the MEG's chart in the appropriate columns under Emission Level Goals based on Ambient Level Goals. These values, multiplied by dilution factors, then describe control levels for emissions that will not cause contaminant concentrations in ambient media to exceed the suggested Ambient Level Goals.

Dilution factors are dimensionless quantities representing the ratio of the concentration of a contaminant in an emission or effluent to the resulting contaminant level in the ambient receiving medium. As an example consider an emission from a stack discharged to the atmosphere. The dilution factor is the concentration of a pollutant in the stack gas divided by the resulting ground level concentration of the pollutant.

Example of Totals recommendations.

AIR

Hydrocarbons: (Includes oxygen containing species as well as simple hydrocarbons.)

I. Environmental Aspects

A. Toxicity

1. Many hydrocarbons are non-toxic and classed as simple asphyxiants or anesthetics with mild central nervous system depression.

2. A few hydrocarbons are extremely toxic, for example, benzene and aldehydes (formaldehyde, acetaldehyde, and acrolein), and concentrations of these pollutants must be carefully controlled.

B. Photochemical precursors are the main reason for controlling hydrocarbons - HC's and NO_x react in presence of UV to produce O_3.

II. Existing Regulations and Recommendations

A. NAAQS primary and secondary standard of 0.24 ppm (160 $\mu g/m^3$) for non-methane hydrocarbons for use as a guide in achieving oxidant standards (based on 3-hour average 6 to 9 am.).

B. NAAQS photochemical oxidants primary and secondary standard of 0.08 ppm (160 $\mu g/m^3$) for a one-hour average expressed as O_3 by Federal Reference Method.

C. Suggested maximum permissible concentrations for most hydrocarbons are typically > 200 ppm (Industrial Hygiene and Toxicology by Patty); this includes many aliphatics, olefins, alicyclics, and some aromatics.

D. HC TLV's range from below 0.1 ppm (for acrolein) to unspecified amounts for simple asphyxiants like methane.

III. Recommendations for MATE values

A. Assumptions

1. Total toxic effect of a pollutant mixture is no greater than the sum of the individual toxicities.

2. The primary reason for control of most hydrocarbons is to control photochemical oxidants; a few hydrocarbons must be controlled for reasons of toxicity.

3. Ground level concentrations are not of primary concern since photochemical reactions pose the biggest problem associated with hydrocarbons.

4. Reasonable dilution factors range from 10 to 1000; as a first approximation, the value of 1000 shall be assumed.

B. Recommendations

Based on the 3-hour average of 0.24 ppm (NAAQS), a total HC concentration (3-hour average) of 200 ppm seems reasonable. Dilution by the factor of 1000 will yield ambient levels below the 0.24 ppm value, aiding in photochemical oxidant control, and the 200 ppm level is at or below the TLV for the bulk of frequently encountered hydrocarbons.

MATE values for certain specific contaminants (aromatics, aldehydes) may be below the 200 ppm level and should not be exceeded.

Example (continued)

AIR

Particulates:

I. Nature of Environmental Problem

A. Toxicity variable with composition

1. Systemic poisons - fumes and dusts of compounds, such as Pb, As, Cd, with both acute and chronic effects.

2. Carcinogens - asbestos, soot, and PPAH.

3. Proliferative dusts (fibrotic pneumoconiosis) - silica, asbestos, coal dust, cotton dust, diatomaceous earths.

B. Nuisance Particulates - small chance of local or systemic effects; irritating and allergy-producing but can be debilitating in massive doses.

II. Size Parameters

A. Dust deposition directly proportional to dust density and particle size and wettability, and in proportional to minute volume and rate of respiration. (Industrial Hygiene and Toxicology by Patty).

B. Disease etiology is related to size of inspired dust particles. In general:

1. Systemic poisons must be <3μ to allow penetration into alveoli and for subsequent diffusion into blood stream.

2. Carcinogens - size is a critical factor.

a. Asbestos - Recent WHO-sponsored IARC conference surmized that there is no level of asbestos which has been proven safe for humans and that fibers with diameters <0.5 μm are the most dangerous in production of tumors. Also, the carcinogenic risk associated with exposure to asbestos is far greater for individuals who smoke (IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man: Asbestos, Vol. 14 - results of a meeting held at Lyon, Dec. 14-17, 1976).

b. PPAH range in size from 0.1 to 10 μ (usually 5 μ or less). The benzene soluble fraction of total particulates consists of PPAH and comprises approximately 10% of total particulates. BAP, an active carcinogen, may comprise 10% of the total PPAH.

3. Proliferative dusts contain free silica or asbestos;

a. Silicosis usually caused by particles ranging from 10 to 0.1 μ (Industrial Hygiene and Toxicology by Patty).

b. Asbestosis most dangerous with particle > 20 μ in length.

C. Nuisance particles must be of respirable size for deleterious effects; < 10 μ

III. Existing Regulations

A. OSHA Air Contaminants Regulations

1. Silica

a. Crystalline (quartz) = $\frac{10 \text{ mg/m}^3}{\%SiO_2 + 2}$ (respirable) = 3.3 mg/m^3 (for 100% SiO_2)

b. Amorphous = 20 mppcf

2. Silicates (< 1% crystalline silica) - 15 to 30 mppcf

Example (continued)

3. Coal dust
    a. (< 5% SiO_2 in respirable fraction) - 2.4 mg/m^3
    b. (> 5% SiO_2 in respirable fraction) - $\frac{10\ mg/m^3}{\%SiO_2+2}$
4. Nuisance dust
    a. Total - 15 mg/m^3
    b. Respirable - 5 mg/m^3
5. Asbestos - 2 fiber/cm^3 > 5 μm in length

B. TLV Data published by ACGIH

1. Silica
    a. Crystalline (quartz) - $\frac{10\ mg/m^3}{\%SiO_2+2}$ (respirable) = 3.3 mg/m^3 (for 100% SiO_2)
    b. Amorphous = 6 mg/m^3 (~ 20 mppcf)
2. Silicates (< 1% quartz) = 15 to 30 mppcf (5 to 10 mg/m^3)
3. Coal dust - 4 mg/m^3
4. Nuisance dust
    a. Total - 10 mg/m^3
    b. Respirable - 5 mg/m^3
5. Asbestos - 5 fibers/cm^3 > 5 μm in length
6. PPAH - 0.2 mg/m^3, as benzene solubles

C. Ambient National Primary Standard - 75 μg/m^3 (Annual geometric mean) 260 μg/m^3 (24-hr)

D. Stationary source emission data

Industry	Affected Facility	Performance Standard (mg/m^3)
Fossil fuel fired steam generator	Entire Facility	~92[a]
Incinerators	Entire Facility	180
Asphalt concrete plants	Entire Facility	90
Secondary lead smelters	Furnace emissions	50
Secondary brass & bronze plants	Furnace emissions	50
Iron and Steel plants	Furnace emissions	50
Sewage treatment plants	Sludge incinerator	70
Primary copper smelters	Entire Facility	50
Primary zinc smelter	Sintering machine	50
Primary zinc smelter	Entire facility	50
Coal preparation plants	Thermal dryer	70
Coal preparation plants	Pneumatic cleaning equip.	40
Steel plants	Control device of electric arc furnace	12
Pulp mills	Furnace emissions	100
Lime kiln - gaseous fossil fuel	Entire Facility	150
Lime kiln - liquid fossil fuel	Entire Facility	300

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[a] Based on 180 μg/k cal input derived from fossil fuel, assuming 1 ton of coal = 5.6 × 10^6 k cal and 3.77 × 10^5 scf/ton stack gas volume.

Example (continued)

IV. Recommendations of MATE

A. Assumptions

1. Reasonable dilution factors are in the range 10 to 1000.
2. Stack heights affect the ground level concentration.

B. Recommendations

A MATE value of 100 mg/m^3 is recommended for the following reasons:

1. Consistent with bulk of existing regulations, implying technological and economic feasibility (Stationary source emission limits range from 12 to 300 mg/m^3 with the majority being between 40 and 100 mg/m^3; median is approximately 80 mg/m^3).
2. Dilution by a factor of 10 meets nuisance particulate TLV of 10 mg/m^3
3. Dilution by a factor of slightly more than 1000 meets the ambient standard of 75 µg/m^3.
4. Can be modified as necessary to account for particulates higher in PAH, silica, or asbestos content or for fumes of toxic materials (e.g., cadmium lead, or beryllium).

Since the dilution factors are variable and highly source specific, no effort has been made to provide the Emission Level Goals with dilution factors applied. Instead, the multiplication exercise is left to the person applying the charts to a specific industrial situation.

Although dilution factors do not appear on the MEG's chart, consideration has been given to the range of factors likely to be encountered in most situations. In spite of the many parameters (listed in Table 13) affecting the magnitude of dilution factors, in general, they may be expected to range between 10 and 10,000 for discharges to air and water. This range is suggested on the basis of best and worst case models of pollutant dispersion.

TABLE 13. PARAMETERS AFFECTING DILUTION FACTORS

Air	Stack flow Stack temperature Stack height Weather conditions: windspeed, sunlight, temperature, pressure Site topography Characteristics of discharge Photochemical reaction kinetics
Water	Flow rate of receiving stream Turbulence of receiving stream Temperature of receiving stream pH of receiving stream Flow rate of discharge Location and design of outfall Temperature of discharge Characteristics of contaminants in discharge: solubility, reactivity, pH, biodegradability, sorption characteristics
Land	Soil characteristics: permeability, pH, caution exchange capacity, weathering, sodium absorption ratio Characteristics of contaminants: ionization, leachability, biodegradability Characteristics of bulk solid waste: surface to volume ratio, density Method of desposition Climate: temperature, rainfall

Parameters considered in the models include stack height, wind speed and atmospheric conditions for air and flow rates of receiving streams for water. These parameters, although not sufficient to fully characterize a dispersion situation, are the most important ones to be considered.

The range of dilution factors for air indicated by these best and worst case models is further supported by a comparison of the pollutant levels meeting current New Stationary Source Performance standards[31] with the levels corresponding to Federal Ambient Air Quality Standards.[36] This comparison requires conversion to concentration units for several of the emission standards but can be carried out with relative ease. Dilution factors indicated for particulates, NO_2 , and SO_2 by this comparison are on the order of 1,000 for most situations.

A great deal of work has been done by various researchers in modeling atmospheric and water dispersion, and it is not the objective of this report to duplicate those efforts. However, it is important to point out that specific dilution factors for a givan set of circumstances may be calculated using fairly reliable dispersion models so that applicable Emission Level Goals based on Ambient Level Goals may be generated.

6.3 ELIMINATION OF DISCHARGE (EOD) EMISSION LEVEL GOALS

Emission Level Goals based on elimination of discharge like those based on Ambient Level Goals incorporate dilution factors. These goals are the most stringent and imply that ambient concentrations of pollutants should not exceed natural background concentrations.

Values appearing on the MEG's chart under Emission Level Goals based on EOD indicate natural background levels. The background information summaries provide this data along with references. Concentrations measured in rural atmosphere are entered for air; when rural atmosphere concentrations are not reported, urban or industrial concentrations, may be entered on the chart with a footnote to characterize the value. Concentrations entered in the MEG's chart for water are for surface waters unless otherwise specified. Levels identified in drinking water and in seawater are included since they provide some indication of natural background concentrations.

SECTION 7

HAZARD INDICATORS

A system has been developed for assigning indicators (X, XX, or XXX) to designate potentially hazardous substances based on values generated by the MEG's methodology. The system provides one simple means of identifying through cursory inspection those pollutants most likely to pose a human health hazard. Numerical hazard potential values for each toxicant are generated through a simple equation which considers toxic and genotoxic potential as well as cumulative or chronic effect characteristics. "X" indicators corresponding to specific ranges of numerical values are then assigned to each substance to indicate its relative hazard potential. The 216 substances currently addressed by the MEG's methodology have in this way been ranked and classified as relatively non-hazardous (no indicator); hazardous (X); very hazardous (XX); or most hazardous (XXX).

7.1 HAZARD POTENTIAL VALUES

Ambient Level Goals for air based on human health effects are used in deriving hazard potential values. Equation 53 is used.

$$N = 2aa'A + 4bB \qquad (53)$$

where: N = the hazard potential level
A = the toxicity based EPC (health effects) for air
B = the zero threshold EPC for air

a, a', and b are weighting factors.

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Values for each of these parameters are assigned as follows:

A is assigned values from 1 to 5 corresponding to EPC's ranging from <0.2 to >200 $\mu g/m^3$ (refer to Table 14).

B is assigned values from 1 to 5 corresponding to zero threshold EPC's ranging from <0.2 to > 20 (refer to Table 14).

TABLE 14. ASSIGNMENT OF VALUES TO A AND B FOR DERIVING HAZARD POTENTIAL VALUES

EPC_I	Value of A	EPC_{II}	Value of B
>200	1	>20	1
≤200	2	≤ 20	2
≤ 40	3	≤ 2	3
≤ 2	4	≤ 0.2	4
≤ 0.02	5	≤ 0.2	5

where: EPC_I is the toxicity based Ambient Level Goal for air (based on health effects).

EPC_{II} is the zero threshold pollutant goal reflecting genotoxic effects.

Weighting factor "a" is included to emphasize the toxic potential term in the expression if data required for the genotoxic term is unavailable. Similarly, "b" emphasizes the genotoxic term if toxic potential data is missing. Values assigned "a" and "b" are as follows:

a = 1 if genotoxic properties are indicated (i.e., B is available).
a = 2 if genotoxic properties are not indicated (B missing).
b = 1 if toxic potential data are available (A is available).
b = 1.5 if toxic potential data are unavailable (A missing).

Weighting factor "a'" is included to increase the N value for those substances indicated to be cumulative or to be hazardous at low concentrations over extended periods of time. a' will be assigned a value of 1.25 if cumulative or chronic characteristics are indicated; otherwise, the value will be 1.0.

Possible values of N resulting from summation of the toxic and genotoxic potential terms may be obtained from the matrix presented in Table 15.

TABLE 15. MATRIX OF HAZARD POTENTIAL (N) VALUES

B \ A	0	1	2	3	4	5
0	0	4 (5)	8 (10)	12 (15)	16 (20)	20 (25)
1	6	6 (6.5)	8 (9)	10 (11.5)	12 (14)	14 (16.5)
2	12	10 (10.25)	12 (13)	14 (15.5)	16 (18)	18 (20.5)
3	18	14 (14.25)	16 (17)	18 (19.5)	20 (22)	22 (24.5)
4	24	18 (18.25)	20 (21)	22 (23.5)	24 (26)	26 (28.5)
5	30	22 (26)	24 (28)	26 (30)	28 (32)	30 (34.5)

Values resulting if a' = 1.25 (i.e., cumulative or chronic characteristics for substance indicated) are shown in parenthesis.

7.2 INDICATORS FROM HAZARD POTENTIAL VALUES

As described in the previous section, hazard potential values range from 4 to 34.5. Table 16 indicates the numerical values required for the assignment of the hazard indicators to appear on MEG charts.

TABLE 16. ASSIGNMENT OF HAZARD INDICATORS BASED ON HAZARD POTENTIAL VALUES

Hazard Potential Value	Assigned Hazard Indicator
$\infty > N \geq 25$	XXX
24 N 19	XX
19 N 13	X
13 N 0	None

The ranges corresponding to various hazard levels have been chosen to result in a reasonable distribution of toxicants among the four levels.

Requirements for assignment of XXX indicator are as follows:

1) $EPC_{II} \leq 0.02$ and $EPC_{I} \leq 40$, or
2) $EPC_{II} \leq 0.02$, $EPC_{I} \leq 200$ and cumulative effect, or
3) $EPC_{II} \leq 0.2$, $EPC_{I} \leq 2$ and cumulative effect, or
4) $EPC_{II} < 0.2$, and $EPC_{I} < 0.02$, or
5) EPC_{II}, unknown, $EPC_{I} < 0.02$ and cumulative effect, or
6) $EPC_{II} < 0.02$, EPC_{I} unknown.

To be assigned indicator XX, a substance must have

1) $EPC_{II} \leq 0.2$ and $EPC_{I} \leq 200$, or
2) $EPC_{II} \leq 2.0$ and $EPC_{I} \leq 40$, or
3) $EPC_{II} \leq 20$, $EPC_{I} \leq 2$ and cumulative effect, or
4) EPC_{II} unknown, $EPC_{I} < 0.02$ or $EPC_{II} < 2$ and cumulative effect, or
5) $EPC_{II} \leq 2$, EPC_{I} unknown.

To get X, a substance must have

1) $EPC_{II} \leq 2$, or
2) $EPC_{II} \leq 20$ and $EPC_{I} \leq 40$, or
3) $EPC_{II} \leq 20$, $EPC_{I} \leq 200$ and cumulative effect, or
4) $EPC_{II} > 20$, $EPC_{I} \leq 0.02$, or
5) $EPC_{II} < 20$, $EPC_{I} \leq 2$ and cumulative effect, or
6) EPC_{II} unknown, $EPC_{I} \leq 2$ or $EPC_{I} \leq 40$ and cumulative effect, or
7) $EPC_{II} \leq 2$, EPC_{I} unknown.

7.3 INDICATOR DISTRIBUTION FOR SUBSTANCES ADDRESSED BY MEG'S.

Hazard potential values have been calculated for those substances addressed by MEG's in this report, and hazard indicators corresponding to the values appear on the MEG's charts included in Appendix E. The distribution of X, XX, and XXX indicators for the 216 substances addressed is shown in Table 17. Sixteen substances or 7.4 percent of the 216 addressed are assigned indicator XXX. Twenty-four (11 percent) receive XX ratings, and 37 (17 percent) receive X rating. Of the 76 substances receiving indicators, 20 percent receive XXX, 31 percent receive XX, and 49 percent receive X.

TABLE 17. SUBSTANCES RECEIVING HAZARD INDICATORS

X	XX	XXX
Formaldehyde	Ethyleneimine	N-Nitrosodimethylamine
Acrolein	Diazomethane	7,12-Dimethylbenz(a)anthrace
Phthalate esters	N,N'-Dimethylhydrazine	Dibenz(a,h)anthracene
Aminotoluenes	N-Nitrosodiethylamine	Benzo(a)pyrene
4-Aminobiphenyl	PCB's	3-Methylcholanthrene
1-Aminonaphthalene	4,6-Dinitro-o-cresol	Beryllium
2-Aminonaphthalene	2,4,6-Trinitrophenol	Arsenic
Monomethylhydrazine	Benz(a)anthracene	Arsine
N,N-Dimethylhydrazine	Dibenzo(a,i)pyrene	Arsenic trioxide
1,2-Diphenylhydrazine	Tetramethyllead	Antimony trioxide
Benzene	Alkyl mercury	Selenium
Nitrobenzene	Organotin	Chromium
4-Nitrobiphenyl	Thallium	Nickel
1-Chloro-2-nitrobenzene	Lead	Cadmium
Dinitrotoluenes	Hydrazine	Mercury
Xylenols	Elemental phosphorus	
2,4-Dichlorophenol	Phosphine	
3-Nitrophenol	Antimony	
4-Nitrophenol	Bismuth	
Dinitrophenols	Hydrogen selenide	
Pyridine	Cobalt	
Dibenz(a,j)acridine	Nickel carbonyl	
Dibenz(a,h)acridine	Copper	
Dibenzo(c,g)carbazole	Uranium	
Tetraethyllead		
Nickelocene		
Copper-8-hydroxyquinoline		
Lithium		
Lithium hydride		
Barium		
Gallium		
Germanium		
Hydrogen cyanide		
Tellurium		
Vanadium		
Manganese		
Silver		

Appendix D lists the specific hazard potential values associated with each substance addressed by MEG's (listed by categories). In addition, the substances are ranked according to the hazard potential values.

SECTION 8

APPLICATION AND EXTENSION FOR THE MEG's REPORT

Results described in this report can be put to use by environmental assessors including engineers, chemical analysts, toxicologists, industrial hygienists, system modeling experts and inspectors or plant monituring personnel. This document can be used as a manual or workbook as it stands, and future supplements to this volume will augment this type of application. The report offers a beginning for goals that address pollutant hazards for a large number of substances, establishing a baseline of information presented in summary form. Continued research and reviews are obviously necessary to fill the many information gaps that still exist.

Figure 5[37] represents an Environmental Protection Agency concept of environmental assessment/control technology development. Multimedia Environmental Goals development contributes to a number of areas in this total program scheme including - (1) evaluation of the current environmental background, (2) environmental objectives development and (3) selection and application of assessment alternatives. The latter, probably the most important function of MEG's, is accomplished by establishing emission level goals. Some further applications obvious from the diagram include the contribution of MEG's to directing the course of environmental data acquisition and their comparison with data from control technology assessments and source analysis models. The comparison results are used to identify needed R & D, control alternatives, and media degradation alternatives. The MEG's also provide a preliminary data base for standards and regulations.

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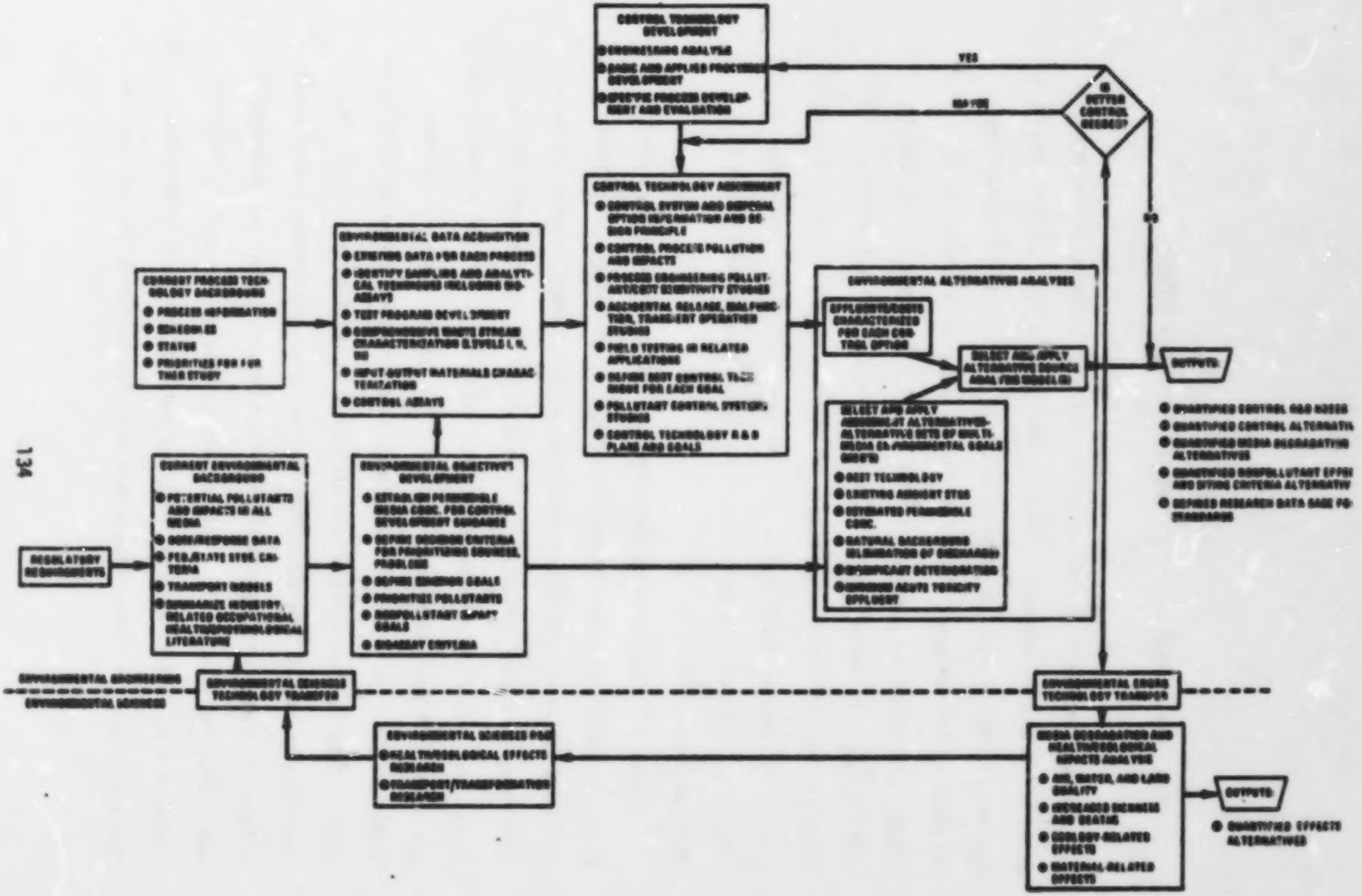

REGULATORY REQUIREMENTS
CURRENT PROCESS TECHNOLOGY BACKGROUND
PROCESS INFORMATION
SCHEDULES
STATUS
PRIORITIES FOR FURTHER STUDY
ENVIRONMENTAL DATA ACQUISITION
EXISTING DATA FOR EACH PROCESS
IDENTIFY SAMPLING AND ANALYTICAL TECHNIQUES INCLUDING BIOASSAYS
TEST PROGRAMS DEVELOPMENT
COMPREHENSIVE WASTE STREAM CHARACTERIZATION (LEVELS I, II, III)
INPUT-OUTPUT MATERIALS CHARACTERIZATION
CONTROL ASSAYS
CURRENT ENVIRONMENTAL BACKGROUND
POTENTIAL POLLUTANTS AND IMPACTS IN ALL MEDIA
DOSE/RESPONSE DATA
FED./STATE STDS. CRITERIA
TRANSPORT MODELS
SUMMARIZE INDUSTRY-RELATED OCCUPATIONAL HEALTH/EPIDEMIOLOGICAL LITERATURE
ENVIRONMENTAL OBJECTIVES DEVELOPMENT
ESTABLISH PERMISSIBLE MEDIA CONC. FOR CONTROL DEVELOPMENT GUIDANCE
DEFINE DECISION CRITERIA FOR PRIORITIZING SOURCES, PROBLEMS
DEFINE EMISSION GOALS
PRIORITIZE POLLUTANTS
NONPOLLUTANT IMPACT GOALS
BIOASSAY CRITERIA
CONTROL TECHNOLOGY DEVELOPMENT
ENGINEERING ANALYSIS
BASIC AND APPLIED PROCESS DEVELOPMENT
SPECIFIC PROCESS DEVELOPMENT AND EVALUATION
CONTROL TECHNOLOGY ASSESSMENT
CONTROL SYSTEM AND DISPOSAL OPTION INFORMATION AND DESIGN PRINCIPLE
CONTROL PROCESS POLLUTION AND IMPACTS
PROCESS ENGINEERING POLLUTANT/COST SENSITIVITY STUDIES
ACCIDENTAL RELEASE, MALFUNCTION, TRANSIENT OPERATION STUDIES
FIELD TESTING IN RELATED APPLICATIONS
DEFINE BEST CONTROL TECHNIQUE FOR EACH GOAL
POLLUTANT CONTROL SYSTEMS STUDIES
CONTROL TECHNOLOGY R & D PLANS AND GOALS
YES
MAYBE
IS BETTER CONTROL NEEDED?
NO
ENVIRONMENTAL ALTERNATIVES ANALYSES
EFFLUENTS/EMISSIONS CHARACTERIZED FOR EACH CONTROL OPTION
SELECT AND APPLY ALTERNATIVE SOURCE ANALYSIS MODEL(S)
SELECT AND APPLY ALTERNATIVE SETS OF MULTIMEDIA ENVIRONMENTAL GOALS (MEG'S)
BEST TECHNOLOGY
EXISTING AMBIENT STDS
ESTIMATED PERMISSIBLE CONC.
NATURAL BACKGROUND (ELIMINATION OF DISCHARGE)
SIGNIFICANT DETERIORATION
MINIMUM ACUTE TOXICITY EFFLUENT
OUTPUTS
QUANTIFIED CONTROL R&D NEEDS
QUANTIFIED CONTROL ALTERNATI
QUANTIFIED MEDIA DEGRADATION ALTERNATIVES
QUANTIFIED NONPOLLUTANT EFFE AND SITING CRITERIA ALTERNATIV
DEFINED RESEARCH DATA BASE FO STANDARDS
ENVIRONMENTAL ENGINEERING
ENVIRONMENTAL SCIENCES
ENVIRONMENTAL SCIENCES TECHNOLOGY TRANSFER
ENVIRONMENTAL ENGRG TECHNOLOGY TRANSFER
ENVIRONMENTAL SCIENCES R&D
HEALTH/ECOLOGICAL EFFECTS RESEARCH
TRANSPORT/TRANSFORMATION RESEARCH
MEDIA DEGRADATION AND HEALTH/ECOLOGICAL IMPACTS ANALYSIS
AIR, WATER, AND LAND QUALITY
INCREASED SICKNESS AND DEATHS
ECOLOGY-RELATED EFFECTS
MATERIAL-RELATED EFFECTS
OUTPUTS
QUANTIFIED EFFECTS ALTERNATIVES

Figure 5. Environmental assessment/control technology development diagram.

Another very important application of the MEG's is their coordination with other environmental assessment methodologies currently being developed. MEG's provide decision criteria (1) in environmental data acquisitions - specifically Level I, II and III analysis procedures - and (2) in environmental alternatives analysis, e.g., the source analysis model for rapid screening, SAM/1A. Figure 6 illustrates the use of a MATE value in deciding whether a Level I sample should be further analyzed at Level II.[38] Here, for example, a substance is associated with a fraction derived from a Level I sample. This fraction, considered as a worst case, may be assumed to consist entirely of the substance in question. The fraction's concentration in the entire sample is then compared with the MATE concentration for the substance to decide if Level II analysis will be conducted for the fraction.[39] One result of this particular application is that, for a number of substances, a large majority of fractions will be eliminated from further analysis.

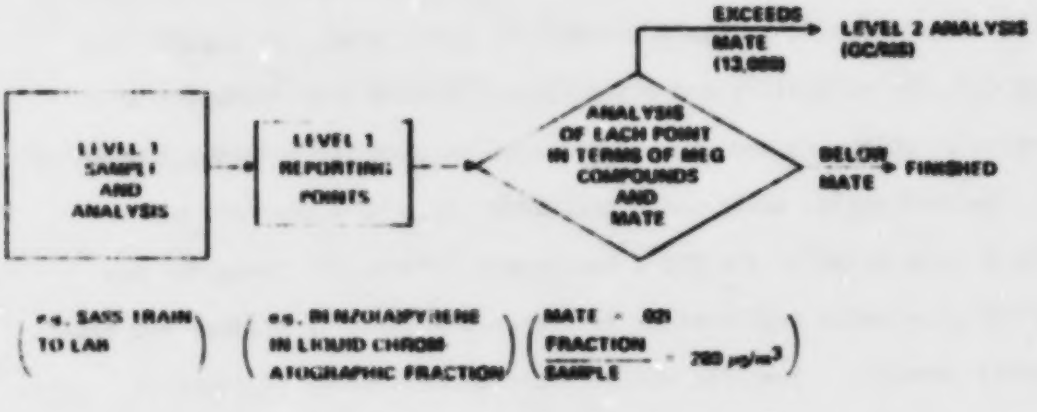
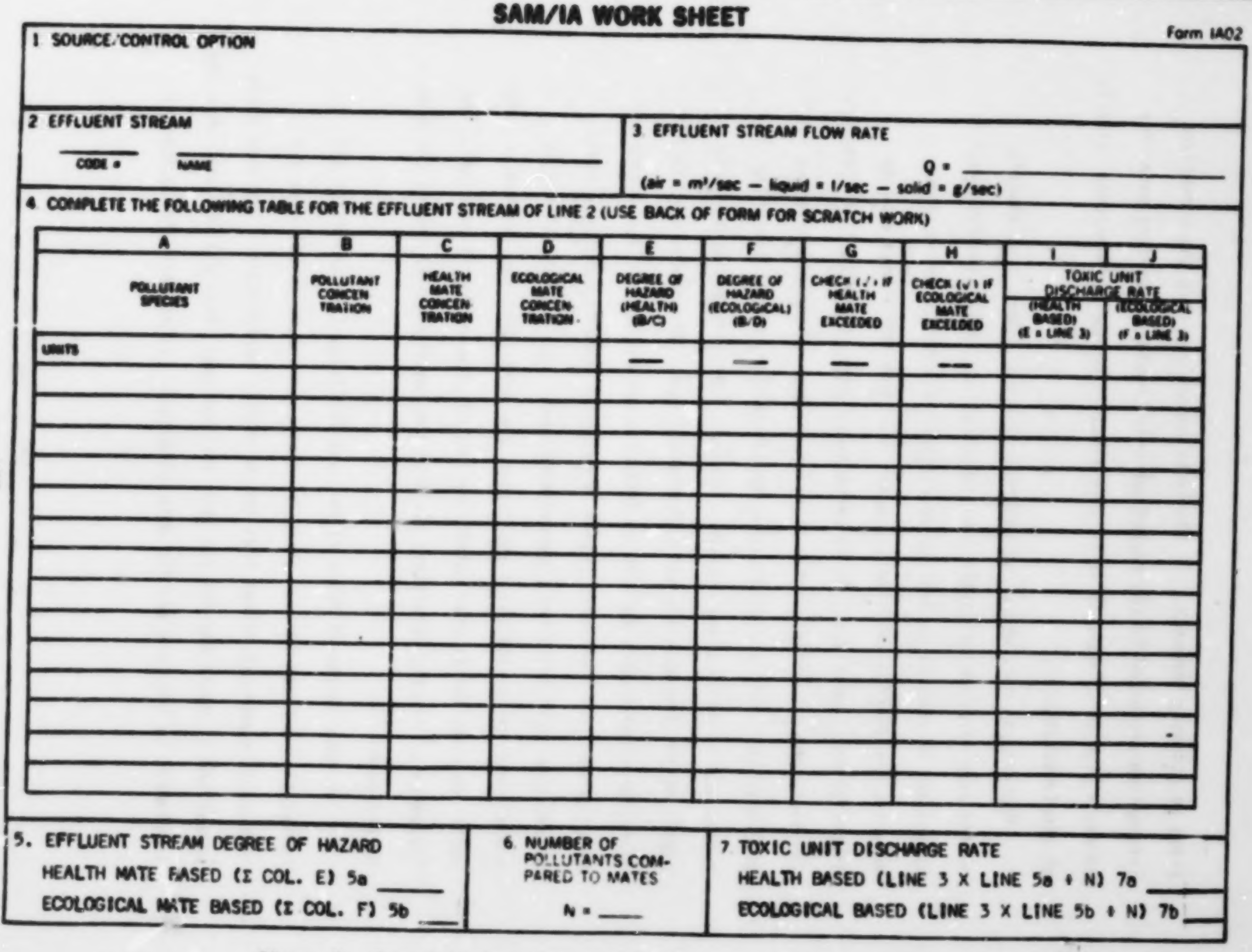

EXCEEDS
MATE
(13,000)
LEVEL 2 ANALYSIS
(GC/MS)
LEVEL 1
SAMPLE
AND
ANALYSIS
LEVEL 1
REPORTING
POINTS
ANALYSIS
OF EACH POINT
IN TERMS OF MEG
COMPOUNDS
AND
MATE
BELOW
MATE
FINISHED
e.g. SASS TRAIN
TO LAB
e.g. BENZO(A)PYRENE
IN LIQUID CHROM
ATOGRAPHIC FRACTION
MATE = .02
FRACTION
SAMPLE
= 280 μg/m³

Figure 6. Decision Chart for Level II Analysis

Figure 7[40] illustrates the use of MATE values in a source analysis worksheet format. This technique[40] is useful for rapid screening of each effluent stream from a specific source. It is based on comparison of effluent concentrations with established MATE goals. MATE's can be used effectively in conjunction with source analyses for (1) ranking of effluent streams, (2) ranking of industries in terms of their probable environmental impact relative to other industries, (3) establishment of additional sampling and analysis priorities, (4) determination of problem pollutants and pollutant priorities, (5) determining effectiveness of various control technology options, and (6) determining the need for control/disposal technology development.

The information for chemical compounds and elements as described on the Background Information Summaries, together with the goals tabulated on each MEG chart, provide indications of (1) sampling levels required to detect environmentally significant emissions, (2) the types of sampling and analysis techniques which might be used most efficiently for detection, (3) media in which particular substances are most likely to be contained, (4) probable process reactions producing a particular compound, (5) volatility and other factors influencing transport of a particular pollutant and (6) which determinations are of highest priority.

Ambient goals, background concentrations, and summarized health effects data noted on the MEG's Background Information Summaries may provide a valuable supplemental reference for those in medical and biological research. Specific MEG's should be considered in light of associated medical data. MEG information may also lend support to such



SAM/IA WORK SHEET

Form IA02

1 SOURCE/CONTROL OPTION

2 EFFLUENT STREAM

CODE = ______ NAME ______

3 EFFLUENT STREAM FLOW RATE

Q = ______

(air = m³/sec — liquid = l/sec — solid = g/sec)

4 COMPLETE THE FOLLOWING TABLE FOR THE EFFLUENT STREAM OF LINE 2 (USE BACK OF FORM FOR SCRATCH WORK)

A	B	C	D	E	F	G	H	I	J
								TOXIC UNIT DISCHARGE RATE	
POLLUTANT SPECIES	POLLUTANT CONCENTRATION	HEALTH MATE CONCENTRATION	ECOLOGICAL MATE CONCENTRATION	DEGREE OF HAZARD (HEALTH) (B/C)	DEGREE OF HAZARD (ECOLOGICAL) (B/D)	CHECK (✓) IF HEALTH MATE EXCEEDED	CHECK (✓) IF ECOLOGICAL MATE EXCEEDED	(HEALTH BASED) (E x LINE 3)	(ECOLOGICAL BASED) (F x LINE 3)
UNITS				—	—	—	—		

5. EFFLUENT STREAM DEGREE OF HAZARD

HEALTH MATE BASED (Σ COL. E) 5a ______

ECOLOGICAL MATE BASED (Σ COL. F) 5b ______

6. NUMBER OF POLLUTANTS COMPARED TO MATES

N = ______

7 TOXIC UNIT DISCHARGE RATE

HEALTH BASED (LINE 3 X LINE 5a ÷ N) 7a ______

ECOLOGICAL BASED (LINE 3 X LINE 5b ÷ N) 7b ______

Figure 7. One of Series of Worksheets for Source Analysis Model 1A (SAM/1A)[40]

areas as bioassay research. It should be emphasized that the summarized information presented in the report can only provide a starting point for in-depth studies attempting definitive findings on the environmental effects of single substances.

MEG data is most useful in research of broad scope. For example, in the area of advanced fossil fuels applications, where environmental assessment or control technology development may be concerned with numerous unresearched substances, goals and other MEG's data provide direction and comparison. In research being done at the Research Triangle Institute on coal gasification, a number of heavy organic substances with possibly high toxic or carcinogenic/teratogenic potential are being quantified in product and byproduct streams. MEG's data, linked with simple dispersion modeling and experimental model parameters for the RTI laboratory system, are applied to determine what measured levels from the experimental gasifier would relate to probable ambient concentrations caused by a full scale coal conversion plant. The findings from this project will determine which substances are most likely to present environmental hazards and to what extent new control technology is required. The influence of process parameters or potential environmental impact can also be evaluated.[41]

The compilation of MEG's allows possibilities for comparison and correlation between various chemical species since empirical data are reduced to numerical values that can be easily manipulated. Complete cross-comparison of goals has not yet been carried out. This will be done when the supplement is complete and the data automated. It appears that automatic data processing will be required for manipulation of the extensive data available. Also, still to be determined are the relative importances of zero threshold considerations, ecological effects, health effects, and current standards on the stringency of the goals set for most substances. While pollutants have been prioritized on the basis of toxic and genotoxic effects from air contamination, the extent of exposure (population affected and potential for emissions) has not been projected. The gross impact of a number of combined substances can be represented by summation calculations, although synergistic/antagonistic effects complicate this approach. Additional work in this area is required before a truly satisfactory assessment scheme can be advanced.

The manner in which the chemical substances have been categorized in this report (Appendix A) offers a guideline which should be useful to those interested in total environmental importance of various types of pollutants.

While the impact of a large amount of data such as that contained in this report may leave the impression of an attempt to over-simplify and - generalize, an important intended application of the report is to narrow the scope of environmental attention for many users. For example, approximately one third of the substances addressed in this report received hazard indicators. The supplemental addendum to this report addressing an additional 450 substances, should have an even lower percentage addressed by indicators (excluding numerous compounds associated with particular elements already indicated in this report to be highly toxic. These compounds owe their toxicity to the element, e.g., Cd, with which they are associated.) When the effects of quantification, i.e., the amount of these toxic substances actually present in the ambient atmosphere or being emitted by specific sources, is taken into account, the number of substances which should receive prompt attention will be much further reduced. Approaches such as the MEG's must be applied to insure that these eliminations have been accomplished in a responsible fashion.

Extensions to the work contained in this report are projected and, to some extent, are already being carried out. Five major aspects of future development of the MEG's are discussed briefly below.

I. MEG's Supplement

Prepare Supplement to current MEG's. An additional 450 substances will be addressed. Background Information Summaries, and MEG's charts will be provided consistent with the format and methodology described in the first MEG's report.

II. Automatic Data Acquisition and Processing

Automatic data acquisition and processing for the MEG's charts is the most efficient way to assemble, update, store, and retrieve the data. The format for the MEG's charts will be programmed so that data may be stored by computer as soon as practical. One benefit is that when programming is complete and sufficient data is stored, it will be possible to better order compounds on the basis of toxicity or other characteristics. This may lead to some pattern recognition which will be helpful in establishing further priorities.

III. New Areas of Investigation to be Incorporated in MEG's II

A. Survey of Research Currently Underway or Planned Which May Significantly Affect MEG's Methodologies and Data Base

It is recognized that presently available data is not, in many cases adequate to conclusively prescribe safe concentrations and establish emission level goals. It is also certain that new data will become available in the future. One such area of research is the effort to describe a molecular structure basis for predicting carcinogenic potential of polycyclics.

B. Survey and Tabulation of Methods and Limits of Detection of the Various Pollutants in Different Media

There is considerable variability in the methods and limits of detection presently utilized in monitoring schemes. Comparison of detection limits with emission and ambient level goals would be useful for pointing out analytical technology gaps.

C. Survey and Comparison for Dispersion Models and Modeling Techniques for Air, Water, and Land

A survey of this type should provide insight into the most important dispersion parameters. From such data reliable dilution factor ranges corresponding to specific ambient and process conditions can be predicted. This is an important aspect of MEG's development since dilution factors are applied to Ambient Level Goals to establish Emission Level Goals.

D. Survey of Control Technologies and Applications

A survey of control technologies, both existing and developing, cross-indexed to each pollutant addressed is required as a data base for engineering estimates of emission levels based on best control technology.

Further indexing of control technologies by industry would be of use in making judgements as to transferability of certain technologies between industries. Such information would be particularly important in estimating Emission Level Goals for 1985 or later.

E. Survey of Engineering Estimates Currently Available

A survey of available measurements and/or engineering estimates of levels of pollution control (achievable through application of specific control technologies) would provide the initial data for establishing emission level goals reasonable for 1983. Technology related estimates should be provided to some extent by information collected in the survey of control technologies and applications. Emphasis will be placed upon retrieving information from EPA engineers and contract monitors and through them, information being generated by contractors.

IV. Development of MEG's II

A. Revision and Refinement of MEG's I Methodology

Models and schemes used in MEG's I will be revised and refined in light of new information. Adjustment in the safety factor applied to TLV's in calculating EPC's may be made based on a dispersion approach. New models will be described and applied where appropriate. A model based on LC_{50}'s will be investigated. New approaches for describing EPC's for zero threshold pollutants are likely to be included.

Typical sources in compliance with existing or proposed standards related to fossil fuels processes will be described. This will allow entries in concentration units under Standards Based on Best Technology on the MEG's charts.

Dilution factor ranges will be discussed based on information compiled in the dispersion model survey.

Consideration will be given to non-chemical degradents and how MEG's might be applied.

B. Update of MEG's I Compilations

The MEG's I compilations will be updated to reflect the MEG's II methodologies and current data. Selected compounds and degradents will be added as appropriate. It is hoped that this may be done through autodata processing.

V. Application of MEG's Methodologies to One Industry

The methodology to be incorporated in MEG's II will be applied to a gasification facility as an example of how the approach can be effectively utilized for environmental assessment and control technology planning.

In summary, preparation of MEG's charts and development of the MEG's methodologies are intended to be useful to several branches of EPA and to others concerned with assessing health effects relative to industry and the environment. The purpose of the MEG's is not to set standards, but to assemble base-line data to be used in selection of areas most in need of Federal regulation. MEG's may serve the field of environmental assessment as tools for industry evaluation and for prioritizing pollutants and degradents. Comparison of industrial emissions to emission level goals based on ambient factors will indicate which industries are most environmentally significant.

MEG's provide for the systematic identification of substances on the basis of industry association and environmental significance, thus, providing the preliminary basis for evaluation of groups of substances and possibly identifying exemplary substances representative of specific chemical groupings. Application of the MEG's approach will help insure efficient monitoring plans for identification of environmentally significant emissions and effluents from existing industry and evaluation of the probable environmental impact of new industries.

MEG's provide initial base-line criteria for judging the appropriateness of existing or proposed regulations in light of ambient and technology factors. Regular updates of the MEG's will be necessary in order to serve this function. The models utilized in the MEG's development provide worst case base-line data for future regulation decisions.

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APPENDIX A

Categories of Organic and Inorganic Substances--
A Means of Organizing Chemical Substances for MEG's Master List

INTRODUCTION

As discussed in Section 3, the MEG's Master List of chemical substances has been divided into categories in an effort to organize the list and to facilitate its use. Brief explanations of each of the categories to which organic substances have been assigned are presented here. The inorganics categories are also listed with elements organized into groups according to the periodic chart of the atoms. An alphabetical index for the chemical categories is included as well. Finally, a supplemental categorization plan for inorganic compounds as an alternate arrangement scheme is offered.

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ORGANICS

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TABLE A-1. ORGANIC CATEGORIES

1	Aliphatic Hydrocarbons
2	Halogenated Aliphatic Hydrocarbons
3	Ethers
4	Halogenated Ethers
5	Alcohols
6	Glycols, Epoxides
7	Aldehydes, Ketones
8	Carboxylic Acids and Derivatives
9	Nitriles
10	Amines
11	Azo Compounds, Hydrazine, and Derivatives
12	Nitrosamines
13	Mercaptans, Sulfides and Disulfides
14	Sulfonic Acids, Sulfoxides
15	Benzene, Substituted Benzene Hydrocarbons
16	Halogenated Aromatic Hydrocarbons
17	Aromatic Nitro Compounds
18	Phenols
19	Halophenols
20	Nitrophenols
21	Fused Aromatic Hydrocarbons
22	Fused Non-Alternant Polycyclic Hydrocarbons
23	Heterocyclic Nitrogen Compounds
24	Heterocyclic Oxygen Compounds
25	Heterocyclic Sulfur Compounds
26	Organometallics

CATEGORY 1: ALIPHATIC HYDROCARBONS

Aliphatic hydrocarbons contain only the elements carbon and hydrogen. They are the simplest organic compounds. Aliphatic compounds may be open-chain compounds or cyclic compounds which resemble open-chain compounds. Aliphatic hydrocarbons, as opposed to aromatic hydrocarbons, undergo addition reactions or free radical substitution reactions.

Physical and chemical properties of aliphatic hydrocarbons are influenced by molecular weight, skeletal structure of compounds, (branched-chain, straight chain, or cyclic), and presence of double or triple bonds and their locations. Except for the smallest compounds, aliphatic hydrocarbons are insoluble in water.

The category is divided into three subcategories:

A. Alkanes and Cyclic Alkanes--These compounds have no double bonds. They are non-polar and relatively inactive.

B. Alkenes, Cyclic Alkenes, and Dienes--These compounds contain one or more double bonds, i.e., carbon atoms joined together by two pairs of electrons. Because of the double bonds, these compounds are more reactive than alkanes. They may be weakly polar.

C. Alkynes--Alkynes are characterized by a triple bond. A triple bond does not react in exactly the same way as a double bond. Alkynes may be reduced to alkenes by the addition of H_2. Another important reaction of alkynes is the addition of H_2O to form aldehydes or ketones.

CATEGORY 2: ALKYL HALIDES

Alkyl halides are aliphatic hydrocarbons in which one or more hydrogens are substituted by chloride, fluoride, or bromide.

Category 2 is subdivided into two subcategories:

A. Saturated Alkyl Halides--Simple alkenes as well as cyclic alkenes containing one or more halogens are included. Such compounds are called saturated because they contain no double bonds.

B. Unsaturated Alkyl Halides--Halgenated non-aromatic hydrocarbons containing one or more double bonds are included. Unsaturated alkyl halides are more reactive than saturated compounds.

CATEGORY 3: ETHERS

Ethers are compounds in which two hydrocarbon moieties are covalently bonded to one oxygen. The general formula can be represented as ROR', ArOR, or ArOAr' where R is any aliphatic group and Ar is any aryl group. Certain ethers are cyclic, and two ether functional groups may occur in the same compound.

Ethers are generally mobile liquids with high vapor pressure. They are weakly polar compounds, commonly used as solvents. Ethers are not highly reactive. The ether linkage is quite stable toward bases, oxidizing agents and reducing agents. They may oxidize in air, however, to form peroxides. Ethers are highly flammable.

Two special kinds of ethers are discussed in separate categories: Furan and its derivitaves are included in Category 24 as heterocyclic oxygen compounds; Exposides are included with glycols in Category 6.

CATEGORY 4: HALOGENATED ETHERS

Chlorinated ethers are prepared by dehydration of chlorinated alcohols. Substitution by chlorine of one or more hydrogens in the alkyl radical of ethers makes most of the resulting chlorinated ethers highly toxic. Several chlorinated ethers are known carcinogens.

CATEGORY 5: ALCOHOLS

Alcohols are characterized by the presence of a hydroxyl group which may be attached to a primary, secondary, or tertiary carbon atom. Alcohols undergo two types of reactions--(1) removal or substitution of the OH group, or (2) removal or substitution of the H from the OH group. The tendency of a compound to react in one of these ways or the other is determined by the type of carbon bonded to the OH.

This category is divided into three subcategories:

A. Primary Alcohols are compounds in which the hydroxyl group is attached to a lone carbon or a primary carbon, i.e., a carbon which is bonded to only one other carbon atom.

B. Secondary Alcohols are compounds in which the hydroxyl group is attached to a secondary carbon. A secondary carbon is a carbon bonded to two other carbon atoms.

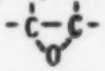
C. Tertiary Alcohols are compounds in which the hydroxyl group is attached to a tertiary carbon, a carbon bonded to three other carbon atoms.

Glycols and phenols are two special types of alcohols which are listed in categories 5 and 18, respectively. Glycols are alcohols containing two hydroxy groups. Phenols contain a hydroxy group as a substituent on a benzene ring.

CATEGORY 6: GLYCOLS, EPOXIDES

Glycols and epoxides and their halogen derivatives are included in this category. Two subcategories are specified:

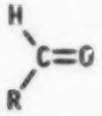
A. Glycols--Glycols are alcohols containing two hydroxyl groups. Most often, the hydroxyl groups are attached to adjacent carbons. Glycols are sometimes referred to as diols.

B. Epoxides--Epoxides are compounds containing the three-membered ring:  They are ethers, but the three membered ring gives them distinct chemical properties. Epoxides react with water to form glycols.

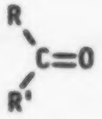
CATEGORY 7: ALDEHYDES, KETONES

Aldehydes and ketones contain the functional group $=C=O$, called the carbonyl group. Because of the tendency of oxygen to acquire electrons the carbonyl group is polarized, leaving it accessible and open to attack by bases. The properties of aldehydes and ketones are similar in many ways because of the common carbonyl functional group; addition reactions are typical. Aldehydes differ in structure from ketones in that they contain only one aliphatic or aromatic group attached to the carbonyl carbon; the ketones have two groups. The structures of aldehydes and ketones are illustrated below:

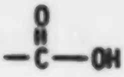
Aldehydes



Ketones



CATEGORY 8: CARBOXYLIC ACIDS AND DERIVATIVES

Carboxylic acids contain the carboxyl group  $-\overset{O}{\overset{\|}{C}}-OH$ attached to either an alkyl or an aryl group. Carboxylic acids are polar; they may be aliphatic or aromatic. Their chief chemical reaction is loss of H^+ and replacement by another group. The ability of these compounds to function as acid is due to the presence of the carbonyl function.

Carboxylic acids react with bases to form salts. Other important reactions include formation of functional derivatives including esters and amides.

This category is divided into four subcategories:

A. Carboxylic Acids--Included are simple aromatic or aliphatic carboxylic acids. Diacids are also included.

B. Carboxylic Acids with Additional Functional Groups--Included are (1) aliphatic acids with additional functional groups on carbon atoms other than the carbonyl carbon; (2) aromatic acids with additional functional groups substituted on the aromatic ring.

C. Amides--Compounds in which the OH of the carboxylic acid is replaced by $-NH_2$ are included in this subcategory. Lactams are a special kind of amide in which a hydrogen attached to the nitrogen is substituted by an alkyl function which forms a cycle with the carbonyl carbon.

D. Esters--Esters are formed when carboxylic acids condense with primary or secondary alcohols. (The H^+ is replaced by the alkyl or aryl portion of the alcohol, and water is formed). Certain esters are grouped for convenience since an almost unlimited number of combinations are possible.

CATEGORY 9: NITRILES

Nitriles are aromatic or aliphatic cyano compounds (RCN, ArCN). Upon hydrolysis they yeild the corresponding carboxylic acid. Most of the cyano compounds have an almond-like odor. The lower molecular weight nitriles are as toxic as inorganic cyanides. Nitriles decompose upon heating to give toxic cyanide vapors.

CATEGORY 10: AMINES

Amines are compounds of the general formula RNH_2, R_2NH, or R_3N, where R is any alkyl or aryl group. Compounds containing two amine functions are called diamines. Both mono and diamines are included in each subcategory. Amines containing halide or hydroxyl groups are also included.

Amines may be aliphatic or aromatic. Aliphatic amines are about as basic as ammonia; aromatic amines are considerably less basic. Amines are converted by acid to their salts. The halides, nitrates, and sulfates are water soluble. Aromatic amines are generally very toxic and may be absorbed through the skin. The presence of the amine function on an aromatic ring activates the ring toward substitution. Aromatic amines are easily oxidized to the corresponding phenols.

This category is divided into four subcategories.

A. Primary Aliphatic Amines and Diamines--Compounds with a single aliphatic group attached to nitrogen are called primary amines. Other functional groups such as hydroxy groups may also be present.

B. Secondary Aliphatic Amines--Compounds in which two alkyl groups are attached to nitrogen are secondary amines. The alkyl groups may be similar or they may be different. Cyclic nonaromatic rings containing nitrogen are included in this subcategory.

C. Aromatic Amines and Diamines--Compounds in which an aromatic ring is attached to nitrogen are called aromatic amines. Other functional groups such as halides may also be attached to the ring.

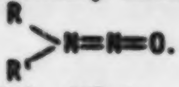
D. Tertiary Amines (Alkyl, Aryl)--Compounds in which three groups, alkyl or aryl, are attached to nitrogen are called tertiary amines.

CATEGORY 11: AZO COMPOUNDS AND HYDRAZINE DERIVATIVES

Azo compounds contain the group -N=N- with a carbon to nitrogen linkage on both sides. The groups attached to the nitrogens may be aliphatic or aromatic. Aromatic azo compounds are highly colored compounds, often called azo dyes. They were first prepared from coal tar and are sometimes referred to as coal tar dyes.

Hydrazine derivatives are similar to azo compounds. They contain the group $-\underset{|}{N}-\underset{|}{N}-$. Hydrazine, the parent compound of these structures, is an inorganic compound and is included in Category 47.

CATEGORY 12: NITROSAMINES

N-Nitrosamines are formed when aliphatic or aromatic secondary amines react with nitrous acid. The structure of nitrosamines is  $\begin{matrix}R\\R'\end{matrix}\!>N{=}N{=}O$. They are generally neutral compounds, insoluble in water and in dilute aqueous mineral acids.

Numerous nitrosamines have demonstrated carcinogenic potential.

CATEGORY 13: THIOLS

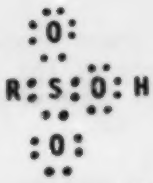
Thiols are alcohols in which sulfur replaces the oxygen in the hydroxyl function. Thiols were formerly called mercaptans. They are formed from alcohols and hydrogen sulfide in the presence of certain catalysts. Thiols are somewhat more acidic than the corresponding alcohols. They are flammable and emit SO_2 upon decomposition.

The common thiols are gases or liquids of high vapor pressures. They have very offensive odors which may cause nausea and headache. Odor is the most important characteristic associated with the thiols. They are generally less toxic than hydrogen sulfide.

CATEGORY 14: SULFONIC ACIDS, SULFOXIDES

These organic sulfur compounds are included as separate subcategories:

A. Sulfonic Acids--The structure of the sulfonic acids is best explained by the following diagram. Each pair of dots represents a pair of electrons.

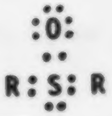


$$\begin{array}{cccc} & :\ddot{O}: & & \\ R: & \overset{\cdot\cdot}{\underset{\cdot\cdot}{S}}: & \underset{\cdot\cdot}{\ddot{O}}: & H \\ & :\underset{\cdot\cdot}{O}: & & \end{array}$$

Only aryl sulfonic acids, formed by sulfonation of a benzene ring, are likely to be present. (Formation of alkyl sulfonic acids from thiols requires a powerful oxidizing agent and is unlikely.)

Sulfonic acids are strong acids. They will probably be isolated as calcium, barium, or lead salts.

B. Sulfoxides--Sulfoxides are oxidized sulfides. The general structure may be represented as follows:



$$\begin{array}{ccc} & :\ddot{O}: & \\ R: & \overset{\cdot\cdot}{\underset{\cdot\cdot}{S}}: & R \end{array}$$

CATEGORY 15: BENZENE, SUBSTITUTED BENZENE HYDROCARBONS

This category contains the aromatic hydrocarbons which are not fused polycyclic. Compounds included are those with simple alkyl or aryl substitution at one or more positions on the benzene ring. Indan, indene, and hydronaphthalenes are included since they are aromatic in only one ring.

CATEGORY 16: HALOGENATED AROMATIC HYDROCARBONS

This category is divided into two subcategories:

A. Compounds in which one or more halogens are attached directly to an aromatic ring are listed in subcategory A. Because of the numerous substitution sites on the ring, several isomers are possible for most of the aryl halides.

The chemical reactivity of these aromatic compounds is influenced substantially by the presence of the halogen on the ring. The ring is deactivated and undergoes further ring substitutions only with difficulty.

C. Halogenated alkyl benzenes (aromatic compounds having an alkyl side chain in which one or more hydrogens are substituted by halogen) do not behave chemically in the same way as aryl halides. The site of the halogen on the side chain is active. The chemical reactions characteristic of these compounds are similar to the reactions of the alkyl halides of Category 2.

CATEGORY 17: AROMATIC NITRO COMPOUNDS

Aromatic compounds containing a nitro substituent on the ring are included in this category. Nitro compounds containing halo, methoxy, alkyl or aryl groups are included here, but nitrophenols are listed in Category 20.

The presence of the nitro groups on a benzene ring deactivates the ring toward further substitution. The positions ortho and para to the nitro group are deactivated more than meta positions.

Nitrobenzenes are catalytically reduced to amines.

CATEGORY 18: PHENOLS

Phenol and phenolic compounds are characterized by a hydroxyl group attached directly to an aromatic ring. Alkyl and aryl substituted phenols and polycyclic phenols are included.

The category is divided into three subcategories.

A. Monohydrics--compounds containing only one hydroxyl group on a ring or substituted ring.

B. Dihydrics, Polyhydrics--compounds in which two or more hydroxyl functions are attached to a ring.

C. Hydroxy Compounds with Fused Rings--polycyclic compounds containing a hydroxyl group.

Halophenols and nitrophenols are listed in Categories 19 and 20 respectively.

CATEGORY 19: HALOPHENOLS

Halophenols are phenolic compounds with one or more halo substituents attached directly to the hydroxy-benzene ring. The presence of the halide significantly increases the acidity of the phenol. It is for this reason that the halophenols are distinguished as a group.

CATEGORY 20: NITROPHENOLS

Nitrophenols are phenolic compounds with one or more nitro groups as substituents on an aromatic ring with a substituent hydroxyl function. Nitrophenols are more acidic than other phenols; the presence of the nitro group on the ring enables the H^+ from the hydroxy function to be released more easily.

Because phenols offer a number of active substitution sites, a variety of isomers may be formed if the ring is nitrated.

CATEGORY 21: FUSED AROMATIC HYDROCARBONS AND THEIR DERIVATIVES

Compounds included in this category are those with two or more fused benzene rings. Alkyl derivatives of such compounds are also included.

Compounds containing the cyclopenta ring (called non-alternant compounds) do not permit the same degree of resonance as compounds which have only fused benzene rings. The behavior of the non-alternant compounds is different as a result of the limited resonance. The non-alternants are not included with the naphthalene family of fused aromatics but are treated separately as Category 22.

Unlike many chemical classes of compounds, toxicity data from one polynuclear aromatic cannot be extrapolated to predict hazards associated with structurally similar compounds. For this category, minor changes in structure may drastically effect oncogenic properties of these compounds. Each compound must be examined individually for indication of its carcinogenic potential.

CATEGORY 22: FUSED NON-ALTERNANT POLYCYCLIC HYDROCARBONS

Compounds included in this category are characterized by the presence of a cyclopenta ring attached to one or more benzene rings. These compounds are distinct from compounds comprised of fused benzene rings. The term non-alternant applies to fully conjugated hydrocarbons that contain rings with an uneven number of carbon atoms. In general, resonant structures cannot be drawn for compounds containing the cyclopenta ring (hence the name non-alternant) as can be done for the fully aromatic fused ring compounds.

Unlike many chemical classes of compounds, toxicity data from one polycyclic hydrocarbon cannot be extrapolated to predict hazards associated with structurally similar compounds. For this category, minor changes in structure may drastically effect oncogenic properties of these compounds. Each compound must be examined individually for indication of its carcinogenic potential.

CATEGORY 23: HETEROCYCLIC NITROGEN COMPOUNDS

A heterocyclic compound is one that contains a ring made up of more than one kind of atom. A nitrogen heterocycle contains nitrogen as a member of an aromatic carbon ring.

This category is divided into four subcategories as follows:

A. Pyridine and Substituted Pyridines--Pyridines are distinguished by the presence of nitrogen as a hetero atom within a six-membered aromatic ring.

B. Fused Six-Membered Ring Heterocycles--These compounds contain two or more fused six-membered rings with one ring containing nitrogen as a hetero atom.

C. Pyrrole and Fused Ring Derivatives of Pyrrole--Compounds in this subcategory are characterized by the five-sided ring containing a nitrogen hetero atom.

D. Nitrogen Heterocycles Containing Additional Hetero Atoms--Included in this subcategory are those compounds containing nitrogen and other atoms, such as sulfur, as hetero atoms in aromatic rings.

Unlike many chemical classes of compounds, toxicity data from one fused heterocycle cannot be extrapolated to predict hazards associated with structurally similar compounds. For this category, minor changes in structure may drastically effect oncogenic properties of these compounds. Each compound must be examined individually for indication of its carcogenic potential.

CATEGORY 24: HETEROCYCLIC OXYGEN COMPOUNDS

Heterocyclic oxygen compounds are characterized by an oxygen atom as a member of an aromatic ring. The oxygen heterocycles are all derived from the five-membered heterocycle ring called furan or from xanthene which contains a six-membered heterocycle ring.

CATEGORY 25: HETEROCYCLIC SULFUR COMPOUNDS

Heterocyclic sulfur compounds are characterized by a sulfur atom as a member of an aromatic ring. The sulfur heterocycles are all derived from the five-membered ring called thiophene.

INORGANICS

TABLE A-2. INORGANIC COMPOUNDS

Group	Category	Element	Group	Category	Element
IA	27	Lithium	VIIA	57	Chlorine
	28	Sodium		58	Bromine
	29	Potassium		59	Iodine
	30	Rubidium	IIIB	60	Scandium
	31	Cesium		61	Yttrium
IIA	32	Beryllium	IVB	62	Titanium
	33	Magnesium		63	Zirconium
	34	Calcium		64	Hafnium
	35	Strontium	VB	65	Vanadium
	36	Barium		66	Niobium
IIIA	37	Boron		67	Tantalum
	38	Aluminum	VIB	68	Chromium
	39	Gallium		69	Molybdenum
	40	Indium		70	Tungsten
	41	Thallium	VIIB	71	Manganese
IVA	42	Carbon	VIII	72	Iron
	43	Silicon		73	Ruthenium
	44	Germanium		74	Cobalt
	45	Tin		75	Rhodium
	46	Lead		76	Nickel
VA	47	Nitrogen		77	Platinum
	48	Phosphorus	IB	78	Copper
	49	Arsenic		79	Silver
	50	Antimony		80	Gold
	51	Bismuth	IIB	81	Zinc
VIA	52	Oxygen		82	Cadmium
	53	Sulfur		83	Mercury
	54	Selenium	IIIB	84	Lanthanides
	55	Tellurium		85	Actinides
VIIA	56	Fluorine			

TABLE A-3. PERIODIC TABLE OF THE ELEMENTS

KEY TO CHART

Atomic Number → 50
Symbol → Sn

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0	Orbit
1 H																	2 He	K
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	K-L
11 Na	12 Mg	Transition Elements					Group 8			Transition Elements		13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	K-L-M
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	-L-M-N
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	-M-N-O
55 Cs	56 Ba	57* La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	-N-O-P
87 Fr	88 Ra	89** Ac	104 —	105 —	106													O-P-Q

*Lanthanides	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu		N-O-P
**Actinides	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr		O-P-Q

Adapted from: Weast, Robert C. (ed.), Handbook of Chemistry and Physics, 56th edition, CRC Press, Inc., Cleveland, Ohio, 1975.

TABLE A-4. ALPHABETICAL INDEX OF ELEMENTS

Element	Category	Element	Category
Aluminum	38	Neodymium	84
Antimony	50	Nickel	76
Arsenic	49	Niobium	66
		Nitrogen	47
Barium	36		
Beryllium	32	Oxygen	52
Bismuth	51		
Boron	37	Phosphorus	48
Bromine	58	Platinum	77
		Potassium	29
Cadmium	82	Praseodymium	84
Calcium	34		
Carbon	42	Rhodium	75
Cerium	84	Rubidium	30
Cesium	31	Ruthenium	73
Chlorine	57		
Chromium	68	Samarium	84
Cobalt	74	Scandium	60
Copper	78	Selenium	54
		Silicon	43
Dysprosium	84	Silver	79
		Sodium	28
Fluorine	56	Strontium	35
		Sulfur	53
Gallium	39		
Germanium	44	Tantalium	67
Gold	80	Tellurium	55
		Thallium	41
Haffnium	64	Thorium	85
		Tin	45
Indium	40	Titanium	62
Iodine	59	Tungsten	70
Iron	72		
		Uranium	85
Lanthanum	84		
Lead	46	Vanadium	65
Lithium	27		
		Yttrium	61
Magnesium	33		
Manganese	71	Zinc	81
Mercury	83	Zirconium	63
Molybdenum	69		

SUPPLEMENTAL CATEGORIZATION OF INORGANIC COMPOUNDS

SUPPLEMENTAL CATEGORIZATION OF INORGANIC COMPOUNDS

The supplemental categorization of inorganic compounds is included as an alternate approach to arranging inorganic substances to be addressed. This categorization scheme groups similar types of pollutants into seven general categories rather than categorizing strictly by elements. Compounds grouped together would probably occur together, and sampling and analysis of compounds in a given category would most likely be similar. As in any prioritization scheme, there are compromises and judgements incorporated in the formulation of this list, and it is not intended to be definitive.

Selection of compounds or elements for six of the seven categories is based upon 1) likelihood of occurrence in significant quantities from fossil fuels processes; or 2) presence likely and toxicity significant.

A brief discussion of the categories follows.

I. Gases - Compounds included in this category are limited to light noncondensable gases comprised of the elements of hydrogen, oxygen, sulfur, carbon, nitrogen, and the halogens. These gases are not decomposed under normal conditions. They are all common air contaminants. Carbon disulfide, although a liquid at room temperature, is included with the gases because of its very high vapor pressure.

II. Selected Elements and Compounds Likely to be Emitted as Vapors, Fumes, or Condensed Particulate - Four types of contaminants are designated under this category: Zero Valence Species, Hydrides, Oxides, and Carbonyls. Elements and compounds included in this category are likely to occur in emissions (especially fugutive emissions) to the atmosphere.

III. Selected Alkali Metal and Alkaline Earth Elements--Ions and Compounds - Alkali metals are those elements occurring in Group 1A of the Periodic Table of Elements. The alkali metals exist in a uniform +1 valence state in all their compounds. Their compounds are always ionic and thus water soluble. Alkaline Earth Elements are the Group 2A elements. They exist in the +2 valence state. The elements of these two groups are strong reducing agents. They will not be present in the elemental state.

IV. Selected Metalloids--Ions and Compounds - Ions and compounds included in this category contain elements of Groups 3A, 4A, 5A, and 6A of the Periodic Chart. Valence states and properties vary greatly ranging from nonmetal to metal.

V. Selected Transition Elements--Zero Valence Species, Ions, and Compounds - Included in this category are the B Family elements of Groups 1 through 8. Properties and valence states are varied although the elements and compounds are almost exclusively metallic.

VI. Anions Containing C, N, O, S, P, F, Cl, Br - Common anions of hydroacids and oxyacids are included in this category. These anions may occur in association with virtually any of the cations of categories III, IV, and V. Generally, the cation rather than the anion is the species identified in analysis, although it is also possible to assay for the anions included here.

VII. Elements Expected to be Present in Minor Amounts - Elements and specific compounds less likely to occur are included in this category.

Representatives of the alkaline metals, alkaline earths, metalloids, and transition elements, including lanthanides and actinides are specified.

APPENDIX B

Master List of Chemical Substances and Physical Agents to be Addressed by Multimedia Environmental Goals

LIST OF CHEMICAL SUBSTANCES AND PHYSICAL AGENTS BY CATEGORIES

(These substances, or groups of substances, have been assessed--on the basis of chemistry, toxicology and association with industrial processes--to be a properly comprehensive compilation for environmental assessment. Additions or deletions should be made when scientific evidence warrants a change.)

ORGANIC COMPOUNDS

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CATEGORY 1: Aliphatic Hydrocarbons

A. Alkanes and Cyclic Alkanes

*Methane
*Ethane
*Propane
*Butanes
Pentanes
Cyclopentane
Hexanes
Cyclohexane
Heptanes
Octanes
Nonanes
Alkanes (C >9)

B. Alkenes, Cyclic Alkenes, and Dienes

*Ethylene
*Propylene
Butylenes
Butadienes
Pentenes
Cyclopentadiene
Hexenes
Cyclohexene
Cyclohexadiene
Heptenes

C. Alkynes

*Acetylene
Propyne
Butyne

*Compounds addressed by MEG's Charts in this report.

CATEGORY 2: Alkyl Halides

A. Saturated Alkyl Halides

- Methyl bromide
- *Methyl chloride
- Methyl iodide
- *Methylene chloride (Dichloromethane)
- Chloroform (Trichloromethane)
- Bromodichloromethane
- Dibromochloromethane
- Bromoform (Tribromomethane)
- Dibromodichloromethane
- Dichlorodifluoromethane
- Trichlorofluoromethane
- Carbon tetrachloride
- 1,2-Dichloroethane (Ethylene chloride)
- Trichloroethane (Methyl chloroform)
- 1,2-Dichloro-1,2-difluoroethane
- Hexachloroethane
- Dichloropropanes
- Bromobutanes
- Hexachlorocyclohexane (Lindane)
- 1-chlorooctane

B. Unsaturated Alkyl Halides

- *Vinyl chloride (Chloroethene)
- 1,2-Dichloroethene
- 1,1-Dichloroethene
- Tetrachloroethene
- Dichloropropenes
- Hexachlorobutadiene
- Hexachlorocyclopentadiene

*Compounds addressed by MEG's Charts in this report.

CATEGORY 3: Ethers

Isopropyl ether
2-Methoxy biphenyl
2-Ethyl-4-methyl-1,2-Dioxolanes
1,3-Dioxane
*1,4-Dioxane

CATEGORY 4: Halogenated Ethers

Chloromethyl methyl ether
1,1'-Dichloromethyl ether
2-Chloro-1,2-epoxypropane
2-Chloroethyl methyl ether
1-Chloro-1,2-oxetane
Chloromethyl ethyl ether
Chloroethyl ethyl ether
1,1'-Dichlorodiethyl ether
1,2-Dichloroethyl ethyl ether
*2,2'-Dichlorodiethyl ether
α-Chlorobutyl ethyl ether
bis-(1-Chloroisopropyl) ether
1,2-Dichlorodiisobutyl ether
Bromophenyl phenyl ether

*Compounds addressed by MEG's Charts in this report.

CATEGORY 5: Alcohols

A. Primary Alcohols

- *Methanol
- *Ethanol
- *1-Propanol
- *n-Butanol
- *Isobutyl alcohol
- *Pentanols (primary)
- α-Hydroxytoluene (Benzyl alcohol)

B. Secondary Alcohols

- *2-Propanol (Isopropyl alcohol)
- *2-Butanol
- *Pentanols (secondary)
- 2,6-Dimethyl-4-heptanol
- α Methyl-α-Hydroxytoluene
- *1-Phenylethanol
- Borneol

C. Tertiary Alcohols

- *t-Butanol
- *t-Pentanol
- α-Terpineol
- Isoborneol

*Compounds addressed by MEG's Charts in this report.

CATEGORY 6: Glycols, Epoxides

A. Glycols

*Ethylene glycol (1,2-Ethanediol)
Propylene glycol (1,2-Propanediol)

B. Epoxides

2,3-Epoxy-1 propanol
*1-Chloro-2,3-epoxypropane (α-Epichlorohydrin)

CATEGORY 7: Aldehydes, Ketones

A. Aldehydes

*Formaldehyde
*Acetaldehyde
*Acrolein
*Propionaldehyde
*Butyraldehyde
3-Methylbutanal
*Benzaldehyde

B. Ketones

Acetone
Tetrachloroacetone
Butanone
*Isophorone
Camphor
Acetophenone
Chlorohydroxy benzophenone
5,6-Benzo-9-anthrone
Dihydro(d)carvone

*Compounds addressed by MEG's Charts in this report.

CATEGORY 8: Carboxylic Acids and Derivatives

A. Carboxylic Acids

*Formic acid
*Acetic acid
Maleic acid
*Benzoic acid
*Phthalic acid
Long chain acids

B. Carboxylic Acids with Additional Functional Groups

*Hydroxyacetic acid
Hydroxybenzoic acids
2-Hydroxypropanoic acid lactone
6-Aminohexanoic acid
β-Propiolactone

C. Amides

*Formamide
Acetamide
6-Hexanelactam (e-caprolactam)

D. Esters

Methyl methacrylate
*Phthalate esters
Adipates
Long chain esters
Methyl benzoate
Phenyl benzoate
Di-2-ethylhexyl phthalate

*Compounds addressed by MEG's Charts in this report.

CATEGORY 9: Nitriles

- *Acetonitrile
- *Acrylonitrile
- 1-Cyanoethane
- Butyronitrile
- 1,3-Dicyano-1-hydroxybutane
- *Benzonitrile
- Naphthonitriles
- *Tetramethylsuccinonitrile

CATEGORY 10: Amines

A. Primary Aliphatic Amines and Diamines

- Methylamine
- *Ethylamine
- *Ethanolamine
- 1,2-Diaminoethane
- 3-Aminopropane
- Propanolamine
- *Butylamines
- *Cyclohexylamine

B. Secondary Aliphatic Amines

- *Ethyleneimine
- *Dimethylamine
- Ethylmethylamine
- Diethylamine
- Morpholine

*Compounds addressed by MEG's Charts in this report.

C. Aromatic Amines and Diamines

*Aniline
*Aminotoluenes (Methyl anilines)
*Dimethylanilines (Xylidines)
Anisidines
1,4-Diaminobenzene
*4-Aminobiphenyl
*Benzidine (4,4'-Diaminodiphenyl)
3,3'-Dichlorobenzidine
4,4'-Methylene bis(2-chloroaniline)
*1-Aminonaphthalene
*2-Aminonaphthalene

D. Tertiary Amines (Alkyl, Aryl)

*N,N-Dimethylaniline

*Compounds addressed by MEG's Charts in this report.

CATEGORY 11: Azo Compounds; Hydrazine Derivatives

*Diazomethane
*Monomethylhydrazine
*N,N-Dimethylhydrazine
*N-N'Dimethylhydrazine
*1,2-Diphenylhydrazine
*p-Dimethylaminoazobenzene

CATEGORY 12: Nitrosamines

*N-Nitroso-dimethylamine
*N-Nitroso-diethylamine
N-Nitroso-dipropylamine
N-Nitroso-diisopropylamine
N-Nitroso-dipentylamine
N-Methyl-N-nitroso-aniline
N-Nitroso-diphenylamine

*Compounds addressed by MEG's Charts in this report.

CATEGORY 13: Thiols, Sulfides and Disulfides

A. Thiols
- *Methanethiol
- *Ethanethiol
- Propanethiols
- *n-Butanethiol
- Benzenethiol
- 1-Anthracenethiol
- Perchloromethanethiol

B. Sulfides, Disulfides
- Dimethyl sulfide
- Diethyl sulfide
- Phenyl sulfide
- Methyl disulfide

CATEGORY 14: Sulfonic Acids, Sulfoxides

A. Sulfonic Acids
- *Benzenesulfonic acid
- 9,10-Anthraquinone-disulfonic acid

B. Sulfoxides
- Dimethyl sulfoxide

*Compounds addressed by MEG's Charts in this report.

CATEGORY 15: Benzene, Substituted Benzene Hydrocarbons

*Benzene
*Toluene
*Ethyl benzene
Styrene
Propyl benzene
Isopropyl benzene
*Indan
*Indene
Butyl benzene
*Biphenyl
4,4'-Diphenylbiphenyl
*Xylenes
Dialkyl benzenes
*Tetrahydronaphthalene
Dihydronaphthalene
Terphenyls
Trimethyl benzenes
Tetramethyl benzenes

CATEGORY 16: Halogenated Aromatic Compounds

A. Ring Substituted Aromatics

*Chlorobenzene
Bromo and Dibromobenzenes
Bromochlorobenzenes
*1,2-Dichlorobenzene
1,3-Dichlorobenzene

*Compounds addressed by MEG's Charts in this report.

*1,4-Dichlorobenzene
Polychlorinated benzenes
*2-Chlorotoluene
Chloronaphthalenes
*Polychlorinated biphenyls

B. Aromatics with Halogenated Alkyl Side Chain
*α-Chlorotoluene
bis-(Chloromethyl)-benzene

CATEGORY 17: Aromatic Nitro Compounds

*Nitrobenzene
*4-Nitrobiphenyl
*1-Chloro-2-nitrobenzene
1-Chloro-4-nitrobenzene
Methoxynitrobenzenes
*Nitrotoluenes
*Dinitrotoluenes

CATEGORY 18: Phenols

A. Monohydrics
*Phenol
*Cresols (Methyl phenols)
2-Methoxyphenol
Ethylphenols

*Compounds addressed by MEG's Charts in this report.

*Phenylphenols
2,2'-Dihydroxydiphenyls
*Xylenols (Dimethyl phenols)
*Alkyl cresols
Polyalkylphenols

B. Dihydrics, Polyhydrics
*Catechol(1,2-Dihydroxybenzene)
1,3-Dihydroxybenzene
1,4-Dihydroxybenzene
1,2,3-Trihydroxybenzenes

C. Fused Ring Hydroxy Compounds
1-Naphthol
2-Naphthol
Phenanthrols
*Indanols
Acenaphthols
2-Hydroxyfluorene
2-Hydroxydibenzofuran

CATEGORY 19: Halophenols

*2-Chlorophenol
*2,4-Dichlorophenol
Pentachlorophenol
Chlorinated cresols

*Compounds addressed by MEG's Charts in this report.

CATEGORY 20: Nitrophenols

*2-Nitrophenol
*3-Nitrophenol
*4-Nitrophenol
*Dinitrophenols
*4,6-Dinitro-o-cresol
Dinitro-p-cresol
2-Amino-4,6-dinitrophenol
*2,4,6-Trinitrophenol

CATEGORY 21: Fused Polycyclic Hydrocarbons

*Naphthalene
Monoalkyl naphthalenes
Phenyl naphthalenes
Dimethyl naphthalenes
Acenaphthene
Acenaphthylene
*Anthracene
2,7-Dimethylanthracene
*Phenanthrene
Methyl phenanthrenes
*Naphthacene
*Benz(a)anthracene
*7,12-Dimethylbenz(a)anthracene
*Benzo(c)phenanthrene
*Chrysene
*Methyl chrysenes
*Triphenylene

*Compounds addressed by MEG's Charts in this report.

*Pyrene
1-Methylpyrene
*Dimethyl pyrenes
1,2-Benzonaphthacene
*Benzo(g)chrysene
*Dibenz(a,c)anthracene
*Dibenz(a,h)anthracene
*Benzo(a)pyrene
*Benzo(e)pyrene
*Perylene
*Picene
*Dibenz(a,h)pyrene
*Dibenzo(a,i)pyrene
*Dibenzo(a,ℓ)pyrene
*Benzo(ghi)perylene
*Coronene

CATEGORY 22: Fused Non-Alternant Polycyclic Hydrocarbons

Dicyclopentadiene
*Fluorene
Cyclopentanonaphthalene
2,3-Benzofluorene
*Fluoranthene
1,2-Benzofluorene
Cyclopenta(def)phenanthrene

*Compounds addressed by MEG's Charts in this report.

Benzo(k)fluoranthene
Benzo(e)fluoranthene
*Benzo(j)fluoranthene
1,2:5,6-Dibenzofluorene
*Benzo(b)fluoranthene
*3-Methylcholanthrene
*Indeno (1,2,3,cd)pyrene
Tribenzylene benzene (Truxene)

CATEGORY 23: Heterocyclic Nitrogen Compounds

A. Pyridine and Substituted Pyridines

*Pyridine
*Picolines
Monosubstituted alkyl pyridines
Phenyl pyridines
Chloropyridine
*Collidines
Disubstituted, Polysubstituted pyridines

B. Fused Six-Membered Ring Heterocycles

*Quinoline, Isoquinoline
*2-Methylquinoline
Dimethylquinolines, Dimethylisoquinolines
*Acridine
Dihydroacridine
Benzo(c)quinoline
Benzo(f)quinoline
Benzo(h)quinoline

*Compounds addressed by MEG's Charts in this report.

Benz(a)acridine
*Benz(c)acridine
*Dibenz(a,j)acridine
*Dibenz(a,h)acridine
*Dibenz(c,h)acridine
*2,3-Benz-4-azafluorene
Indeno(1,2,3,ij)isoquinoline

C. Pyrrole and Fused Ring Derivatives of Pyrrole

*Pyrrole
*Indole
Methylindoles
*Carbazole
Methylcarbazoles
Benzo(a)carbazole
*Dibenzo(a,i)carbazole
*Dibenzo(c,g)carbazole
*Dibenzo(a,g)carbazole

D. Nitrogen Heterocycles Containing Additional Hetero Atoms

Benzothiazole
Methylbenzothiazoles

CATEGORY 24: Heterocyclic Oxygen Compounds

Furan
Benzofurans
Dibenzofuran
Methyldibenzofurans
Naphthofurans
Benzo(b)naptho(2,3-d)furan

*Compounds addressed by MEG's Charts in this report.

Phenanthro(9,10-b)furan
1,9-Benzoxanthene
*Tetrahydrofuran

CATEGORY 25: Heterocyclic S Compounds

*Thiophene
*Methyl thiophenes
Dimethylthiophenes
Trimethyl and Tetramethyl thiophenes
2,2-Bithiophene
*Benzo(b)thiophene
Dibenzothiophene
Benzonaphthathiophene

CATEGORY 26: Organometallics

A. Alkyl or Aryl Organometallics

Trimethyl arsine
*Tetramethyllead
*Tetraethyllead
*Alkyl mercury
*Organotin
Organogermanes
Alkyl stibines

*Compounds addressed by MEG's Charts in this report.

B. Sandwich Type Organometallics

*Ferrocene
*Nickelocene
Dibenzene chromium

C. Metal Porphyrins and Other Chelates

Complexed Vanadium
  Nickel
  *Copper -8-Hydroxyquinoline
  Iron
  Tin
  Zinc

*Compounds addressed by MEG's Charts in this report.

ELEMENTS AND INORGANIC COMPOUNDS

27. *Lithium, Li
    A. Lithium Ion, Li^+
    B. Significant Lithium Compounds
        Lithium Fluoride, LiF
        Lithium Carbonate, Li_2CO_3
        *Lithium Hydride, LiH

28. Sodium, Na
    A. Sodium Ion, Na^+
    B. Sodium Hydroxide, NaOH
29. *Potassium, K
    A. Potassium Ion, K^+
    B. Potassium Hydroxide, KOH
30. Rubidium, Rb
    A. Rubidium Ion, Rb^+

31. Cesium, Cs
    A. Cesium Ion, Cs^+

32. *Beryllium, Be
    A. Beryllium Ion, Be^{++}
    B. Significant Compounds
        Beryllium Oxide, BeO
        °Beryl, $BeO \cdot Al_2O_3 \cdot SiO_2$

33. *Magnesium, Mg
    A. Magnesium Ion, Mg^{++}
    B. Significant Compounds
        *Magnesium Oxide, MgO
        Magnesium Fluoride, MgF_2
        Magnesium Sulfate, $MgSO_4$
        °Magnesite, $MgCO_3$
        °Dolomite, $MgCO_3 \cdot CaCO_3$
        °Asbestos

*Compounds addressed by MEG's Charts in this report.

°Indicates common mineral associations.

34. Calcium, Ca
    A. Calcium Ion, Ca^{++}
    B. Significant Compounds
       Calcium Fluoride, CaF_2
       Calcium Carbonate, $CaCO_3$
       Calcium Sulfate, $CaSO_4$
      °Dolomite, $MgCO_3 \cdot CaCO_3$ (See Category 33)

35. *Strontium
    A. Strontium Ion, Sr^{++}
    B. Significant Compounds
       Strontium Fluoride, SrF_2
       Strontium Sulfate, $SrSO_4$

36. *Barium, Ba
    A. Barium Ion, Ba^{++}
    B. Significant Compounds
       Barium Sulfide, BaS
       Barium Thiocarbonate, $BaCS_3$
       Barium Fluoride, BaF_2
       Barium Carbonate, $BaCO_3$
       Barium Sulfate, $BaSO_4$

37. *Boron, B
    A. Ions containing Boron
       Borate, $BO_3^{\equiv}$
       Metaborate, BO_2^-
    B. Significant Compounds
      *Boron Oxide, B_2O_3

38. *Aluminum, Al
    A. Aluminum Ion, Al^{+++}

*Compounds Addressed by MEG's Charts in this report.
°Indicates common mineral association.

B. Significant Compounds
*Aluminum Oxide, Al_2O_3
°Bauxite, $Al_2O_3 \cdot 3H_2O$
°Hydrated Aluminum Silicate

C. Alums $[M\ Al\ (SO_4)_2 \cdot (H_2O)_x]$ Where M is a monovalent metal

39. *Gallium, Ga
A. Elemental Species, Ga
B. Gallium Ions
Gallons, Ga^{+1}
Gallic, Ga^{+3}
C. Significant Compounds
Gallium Sesquioxide, Ga_2O_3

40. Indium, In
A. Indium Ion, In^{+3}

41. *Thallium, Tl
A. Thallium Ions
Thallous, Tl^{+1}
Thallic, Tl^{+3}

42. Carbon, C
A. Elemental Species
°Coal
B. Radicals Containing Carbon
Carbide, C-
Carbonate, CO_3^{-2}
Bicarbonate, HCO_3-
Cyanide, CN- (See Category 47)
Thiocyanate, SCN- (See Category 53)
Carbonyl, CO=

*Compounds addressed by MEG's Charts in this report.
°Indicates common mineral associations.

C. Significant Compounds

- *Carbon Monoxide
- *Carbon Dioxide
- Carbon Disulfide (See Category 53)
- Carbonyl Sulfide (See Category 53)
- Hydrogen Cyanide (See Category 47)
- Carbonyl Chloride (Phosgene)) $COCl_2$ (See Category 57)

43. Silicon, Si

A. Ions Containing Silicon

- Orthosilicate, SiO_4^{-2}
- Metasilicate, $(SiO_3)_n$

B. Significant Compounds

- Silane, SiH_4
- Silicon Dioxide, SiO_2
- Silicon Disulfide, SiS_2
- Silicon Carbide, SiC

44. *Germanium, Ge

A. Germanium Ions

- Germanous, Ge^{+2}
- Germanic, Ge^{+4}

B. Significant Compounds

- Germanous Sulfide
- Germanic Sulfide, GeS_2
- Germane, GeH_4
- Germanium Oxide, GeO_2
- Organometallics (See Category 26)

45. Tin, Sn

A. Ions of Tin

- Stannous, Sn^{+2}
- Stannic, Sn^{+4}

*Compounds addressed by MEG's Charts in this report.

B. Significant Compounds
Tin oxide, SnO_2
Organometallics (See Category 26)

46. *Lead, Pb
A. Elemental Species, Pb
B. Lead Ions
Plumbous, Pb^{+2}
Plumbic, Pb^{+4}
C. Significant Compounds
Lead Monoxide, PbO
Lead Sulfate, $PbSO_4$
Lead Sulfide, PbS
Lead Carbonate, $PbCO_3$
Lead Phosphate, $Pb_3(PO_4)_2$
Lead Chromate, $PbCrO_4$
Lead arsenate, $PbHAsO_4$
Lead Molybdate, $PbMoO_4$
Organometallics (See Category 26)

47. Nitrogen, N
A. Ions Containing Nitrogen
Nitride, N
Nitrate, NO_3^-
Nitrite, No_2^-
Ammonium, NH_4^+
*Cyanide CN-
Thiocyanate, SCN- (See Category 53)
B. Significant Compounds
Nitrogen Oxides, N_2O, NO_2, N_2O_4, N_2O_3, N_2O_5
*Ammonia, NH_3
*Hydrazine
*Hydrogen Cyanide, HCN

*Compounds addressed by MEG's Charts in this report.

*Alkali Cyanides, NaCN, KCN
Cyanogen, C_2N_2
Nitric acid, HNO_3

48. *Phosphorus, P
A. Ions Containing Phosphorus
*Phosphate, PO_4^{-3}
Phosphite, PO_3^{-3}
Biphosphate, $H_2PO_4^-$
B. Significant Compounds
*Phosphine, PH_3
Phosphoric acid, H_3PO_4
Phosphorus pentasulfide, P_2S_5

49. *Arsenic, As
A. Elemental Species
Metallic Arsenic
B. Ions Containing Arsenic
Arsenous, As^{+3}
Arsenic, As^{+5}
Arsenate, AsO_4^{-3}
Arsenite, AsO_3^{-3}
Arsenide, As^{-3}
C. Significant Compounds
*Arsine, AsH_3
*Arsenic Trioxide, As_2O_3
Nickel Arsenic Sulfide (See Category 76)
Nickel Arsenide, NiAs (See Category 76)
Lead Arsenate, $PbHAsO_4$ (See Category 46)
Cobalt Arsenic Sulfide, CoAsS (See Category 74)
Cobalt Arsenide, $CoAs_2$ (See Category 74)
Organometallics (See Category 26)

*Compounds addressed by MEG's Charts in this report.

50. *Antimony, Sb
    A. Elemental Species, Sb Metal
    B. Ions Containing Antimony
        Antimonous, (stibnous) Sb^{+3}
        Antimonic (stibnic) Sb^{+5}
    C. Significant Compounds
        Stibine, SbH_3
        °Antimonous Sulfide, Sb_2S_3
        *Antimony Trioxide, Sb_2O_3
        Nickel Antimonide, NiSb (See Category 76)
        Alkyl stibines, SbR_3 (See Category 26)

51. *Bismuth, Bi
    A. Elemental Species, Bi
    B. Bismuth Ions
        Bismuthous, Bi^{+3}
        Bismuthic, Bi^{+5}

52. Oxygen, O
    A. Significant Compounds
        *Ozone, O_3

53. Sulfur, S
    A. Elemental Species
        Rhombic, S_8
    B. Ions Containing Sulfur
        Sulfide, S^{-2}
        Sulfate, SO_4^{-2}
        Sulfite, SO_3^{-2}
        Thiocyanate, SCN^-
    C. Sulfur Oxides
        Sulfur Dioxides, SO_2
        Sulfur Trioxide, SO_3
        *Carbonyl Sulfide, COS
    D. Other Significant Compounds
        *Hydrogen Sulfide, H_2S
        *Carbon Disulfide, CS_2
        Sulfuric Acid, H_2SO_4

*Compounds Addressed by MEG's Charts in this report.
°Indicates common mineral associations.

54. *Selenium, Se

- A. Elemental Species, Se
- B. Ions Containing Selenium
  - Selenide, Se^{-2}
  - Selenites, SeO_3^{-2}
  - Selenates, SeO_4^{-2}
- C. Significant Compounds
  - *Hydrogen Selenide, H_2Se
  - Carbon Diselenide, CSe_2
  - Selenium Dioxide, SeO_2

55. *Tellurium, Te

- A. Ions Containing Tellurium
  - Telluride, Te^{-2}
  - Tellurite, TeO_3^{-2}
  - Tellurate, TeO_4^{-2}

56. Fluorine, F

- A. Fluoride Ion, F^-
- B. Significant Compounds
  - Hydrogen Fluoride, HF

57. Chlorine, Cl

- A. Chloride Ion, Cl^-
  - Hypochlorite ClO^-
  - Chlorite ClO_2^-
  - Chlorate ClO_3^-
- B. Significant Compounds
  - Hydrogen Chloride, HCl
  - Chlorine Dioxide, ClO_2
  - Carbonyl Chloride (Phosgene), $COCl_2$

*Compounds addressed by MEG's Charts in this report.

58. Bromine, Br
   A. Bromide Ion, Br^-
   B. Significant Compounds
      Hydrogen Bromide, HBr

59. Iodine, I
   A. Iodide Ion, I^-

60. *Scandium, Sc
   A. Scandium Ion, Sc^{+3}

61. Yttrium, Y
   A. Yttrium Ion, Y^{+3}

62. *Titanium, Ti
   A. Titanium Ions
      Titanous, Ti^{+3}
      Titanic, Ti^{+4}
   B. Significant Compounds
      Titanium Dioxide, TiO_2

63. Zirconium, Zr
   A. Zirconium Ion, Zr^{+4}
   B. Significant Compounds
      Zirconium Dioxide, ZrO_2

64. Hafnium, Hf
   A. Hafnium Ion, Hf^{+4}

65. *Vanadium, V
   A. Elemental Species, V
   B. Ions Containing Vanadium
      Vanadic, V^{+3}
      Vanadyl, VO^{+2}
      Orthovanadate, VO_4^{-4}

*Compounds addressed by MEG's Charts in this report.

Metavanadate, VO_3
Vanadylic, VO^{+3}

C. Significant Oxides
Vanadium Monoxide, VO
Vanadium Trioxide, V_2O_3
Vanadium Tetraoxide, V_2O_4
Vanadium Pentoxide, V_2O_5

D. Other Significant Compounds
Vanadium Monosulfide, VS
Vanadium Carbide, VC
Vanadium Nitride, VN
Vanadyl Sulfate, $VOSO_4$
Organometallics (See Category 26)

66. Niobium, Nb

A. Niobium Ions
Niobus, Nb^{+3}
Niobic, Nb^{+5}

B. Significant Compounds
Niobium Oixdes, NbO, Nb_2O_5

67. Tantalum, Ta

A. Tantalum Ion, Ta^{+5}

B. Significant Compounds
Tantalum Oxide, Ta_2O_5

68. *Chromium, Cr

A. Ions Containing Chromium
Chromous, Cr^{+2}
Chromic, Cr^{+3}
Chromates, CrO_4^{-2}

*Compounds addressed by MEG's Charts in this report.

Chromites, Cr_2O_4

Dichromates, $Cr_2O_7^{-2}$

B. Significant Compounds

Chromium Carbonyl, $Cr(CO)_6$

Chromium Sulfide, Cr_2S_3

Chromic Oxide, Cr_2O_3

°Chromite Mineral, $FeO \cdot Cr_2O_3$

Hydrous Chromium Phosphate, $CrPO_4 \cdot XH_2O$

Lead Chromate, $PbCrO_4$ (See Category 46)

Iron Chromate, $FeCrO_4$

Organometallics (See Category 26)

69. *Molybdenum, Mo

A. Ions Containing Molybdenum

Molybdenous, Mo^{+2}

Molybdic, Mo^{+3}

Molybdate, MoO_4^{-2}

B. Significant Compounds

Molybdenum Sulfide, MoS_2

Lead Molybdate, $PbMoO_4$ (See Category 46)

Molybdenum Trioxide, MoO_3

70. *Tungsten, W

A. Tungsten Ions, W^{+2}, W^{+4}, W^{+5}, W^{+6}, WO_4^{-2}

B. Significant Compounds

°Tungsten Disulfide, WS_2

Tungsten Trioxide, WO_3

°Wolframite Mineral, $FeWO_4 \cdot MnWO_4$

*Compounds addressed by MEG's Charts in this report.

°Indicates common mineral associations.

71. *Maganese, Mn

A. Ions Containing Manganese
   Manganous, Mn^{+2}
   Manganic, Mn^{+3}
   Permanganate, MnO_4^-

B. Significant Compounds
   Manganous Oxide, MnO
   Manganese Dioxide, MnO_2
   Manganese Carbonate, $MnCO_3$
   Manganous Sulfate, $MnSO_4$
   Manganese Sulfide, MnS_2

72. Iron,Fe

A. Ions Containing Iron
   Ferrous, Fe^{+2}
   Ferric, Fe^{+3}
   Ferrocyanide, $Fe(CN)_6^{-4}$
   Ferricyanide, $Fe(CN)_6^{-3}$

B. Significant Compounds
   Ferrous Oxide, FeO
   Ferric Oxide, Fe_2O_3
   Ferric Hydroxide (hydrated) $Fe_2O_3 \cdot XH_2O$
   Iron Sulfides, FeS, Fe_2S_3
   °Pyrite, FeS_2
   °Magnetite, $FeO \cdot Fe_2O_3$
   Chalcopyrite Mineral, $CuFeS_2$ (See Category 78)
   Potassium Iron Silicate, $KFeSi_2O_6$
   Iron Chromate, $FeCrO_4$ (See Category 68)
   Iron Carbonyls, $Fe(CO)_5$, $Fe(CO)_9$, $Fe_3(CO)_{12}$

73. Ruthenium, Ru

A. Ruthenium Ion, Ru^{+3}

*Compounds addressed by MEG's Charts in this report.

°Indicates common mineral associations.

74. *Cobalt, Co
   - A. Cobalt Ions
      - Cobaltous, Co^{+2}
      - Cobaltic, Co^{+3}
   - B. Significant Compounds
      - Cobaltous Carbonate, Hydrated, $CoCO_3 \cdot CH_2O$
      - Cobalt Carbide, Co_3C
      - Cobalt Sulfides, CoS, Co_2S_3
      - °Cobalt Arsenic Sulfide, CoAsS
      - °Cobalt Arsenide, $CoAs_2$
      - Cobalt Carbonyl, $Co(CO)_4$
      - Cobaltous Oxide, CoO
      - Cobaltous Hydroxide, $Co(OH)_2$

75. Rhodium, Rh
   - A. Rhodium Ion, Rh^{+3}

76. *Nickel, Ni
   - A. Nickel Ions
      - Nickelous, Ni^{+2}
      - Nickelic, Ni^{+3}
   - B. Significant Compounds
      - *Nickel Carbonyl, $Ni(CO)_4$
      - °Nickelous Sulfide, NiS
      - °Nickel Arsenide, NiAs
      - Nickel Oxide, NiO
      - °Nickel Antimonide, NiSb
      - °Nickel Arsenic Sulfide, NiAsS
      - Organometallics (See Category 26)

77. Platinum, Pt
   - A. Elemental Species, Pt

*Compounds addressed by MEG's Charts in this report.

°Indicates common mineral associations.

78. *Copper
   A. Elemental Species, Cu
   B. Copper Ions
      Cuprous, Cu^+
      Cupric, Cu^{+2}
   C. Significant Compounds
      Copper Fluoride, CuF_2
      Copper Oxides, CuO, Cu_2O
      Copper Sulfate, $CuSO_4$
      Copper Sulfides, CuS, Cu_2S
      Copper Carbonate, $CuCO_3$
      Organometallics (See Category 26)
      °Chalcopyrite Mineral, $CuFeS_2$
      °Malachite Mineral, $CuCO_3 \cdot Cu(OH)_2$

79. *Silver, Ag
   A. Silver Ion, Ag^+
   B. Significant Compounds
      Silver Chloride, $AgCl$
      Silver Cyanide, $AgCN$
      Silver Sulfide, Ag_2S

80. Gold, Au
   A. Elemental Species

81. *Zinc, Zn
   A. Elemental Species, Zn
   B. Zinc Ion, Zn^{+2}
   C. Significant Compounds
      Zinc Oxide, ZnO
      Zinc Sulfate, $ZnSO_4$
      Zinc Sulfide, ZnS
      Organometallics (See Category 26)

*Compounds addressed by MEG's Charts in this report.

82. *Cadmium, Cd

A. Elemental Species, Cd

B. Cadmium Ion, Cd^{+2}

C. Significant Compounds

Cadmium Sulfide, CdS

Cadmium Oxide, CdO

83. *Mercury, Hg

A. Elemental Species, Hg

B. Mercury Ions

Mercurous, Hg_2^{++}

Mercuric, Hg^{++}

C. Significant Compounds

Mercuric Sulfide, HgS

Mercuric Chloride, $HgCl_2$

Organometallics (See Category 26)

84. Lanthanides

Lanthanum, La, La^{+3}

Cerium, Ce, Ce^{+3}, Ce^{+4}, Ce_2O_3

Praseodymium, Pr, Pr^{+3}

Neodymium, Nd, Nd^{+3}

Samarium, Sm, Sm^{+3}

Dysprosium, Dy, Dy^{+3}

85. Actinides

*Uranium, U, U^{+6}

Thorium, Th, Th^{+4}

*Compounds addressed by MEG's Charts in this report.

PHYSICAL AGENTS

A. Complex Chemical Compositions

- Asbestos
- Ash
- Brine
- Carbon
- Coal Dust
- Coal Tar
- Coal Tar Aerosol
- Coke
- Naphtha
- Oil
- Particulates
- Petroleum Distillates
- Salts
- Sludge
- Soot
- Sulfur (solid)
- Sulfur dust
- Sulfuric acid mist
- Tar
- Turpentine

B. Non-Chemical

- Noise
- Heat
- Radiation
- Non-Pollutants

APPENDIX C

Tabulations of Minimum Acute Toxicity Effluent (MATE) Values for Chemical Substances Appearing on the Master List

INTRODUCTION

MATE's describe very approximate concentrations for contaminants in source emissions to air, water, or land that will not evoke significant or irreversible harmful responses in human populations or ecosystems that might be exposed, provided the exposures are of limited duration. An effort has been made to provide at least preliminary MATE's for all the entries on the master list, even though data collection is substantial only for 216 substances. MATE's for compounds or elements other than those addressed by background information summaries and MEG charts (in appendix A of this report) are based on extremely limited research and are subject to revision. It is certain that many of the "N" designations or blanks in these MATE tabulations will be replaced by appropriate numbers and that errors in the tabulation will become apparent as a result of research required for preparation of the first MEG supplement.

Values for MATE's are expressed in scientific notation to facilitate comparison and to simplify presentation; the number following the "E" is understood to be the exponent of 10. For example, 4.2E3 means 4.2×10^3, or 4,200.

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Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
1A	Methane	3.3E5 (5000)		4.9E7	>1.0E5	9.8E4	>2.0E2
	Ethane	6.1E6 (5000)		9.2E7	N	1.8E5	N
	Propane	9.0E6 (5000)		1.4E8	>1.0E5	2.8E5	>2.0E2
	Butanes	1.4E6 (600)		2.1E7	>1.0E5	4.2E4	>2.0E2
	Pentanes	1.8E6 (600)		2.7E7	1.0E3	5.4E4	2.0E0
	Cyclopentane	N		N	>1.0E5	N	>2.0E2
	Hexanes	3.6E5 (100)		5.4E6	>1.0E5	1.1E4	>2.0E2
	Cyclohexane	1.1E6 (300)		1.6E7	1.0E3	3.2E4	2.0E0
	Heptanes	1.6E6 (400)		2.4E7	1.0E5	4.8E4	2.0E2
	Octanes	1.5E6 (300)		2.2E7	N	4.4E4	N
	Nonanes	1.1E6 (200)		1.6E7	N	3.2E4	N
	Alkanes ($C > 9$)	N		N	N	N	N
1B	Ethylene	5.7E6 (5000)	1.0E0	8.6E7	1.0E4	1.7E5	2.0E1
	Propylene	8.6E6 (5000)		1.3E8	1.0E5	2.6E5	2.0E2
	Butylenes	N		N	N	N	N
	Butadienes	2.2E6 (1000)		3.3E7	1.0E3	6.6E4	2.0E0
	Pentenes	N		N	N	N	N

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		μg/g Solid Waste (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
1B (cont'd)	Cyclopentadienes	2.0E5 (75)		3.0E6	N	6.0E3	N
	Hexenes	N		N	N	N	N
	Cyclohexene	1.0E6 (300)		1.5E7	N	3.0E4	N
	Cyclohexadiene	N		N	N	N	N
	Heptenes	N		N	1.0E5	N	2.0E2
1C	Acetylene	5.3E6 (5000)	1.1E5 (100)	8.0E7	N	1.6E5	N
	Propyne	1.7E6 (1000)		2.5E7	N	5.0E4	N
	Butyne	N		N	N	N	N
2A	Methyl bromide	6.0E4 (15)		9.0E5	>1.0E5	1.8E3	>2.0E2
	Methyl chloride	2.1E5 (100)		3.2E6	>1.0E5	6.4E3	>2.0E2
	Methyl iodide	8.5E2		1.3E4	N	2.6E1	N
	Methylene chloride (Dichloromethane)	2.6E5 (75)		3.9E6	1.0E4	7.8E3	2.0E1
	Bromochloromethane	1.1E6 (200)		1.7E7	N	3.4E4	N
	Chloroform (Trichloromethane)	1.2E5 (25)		6.0E5	N	1.2E3	N
	Bromodichloromethane	N		N	N	N	N
	Dibromochloromethane	N		N	N	N	N
	Bromoform (Tribromomethane)	5.0E3 (0.5)		7.5E4	N	1.5E2	N
	Dibromodichloromethane	N		N	N	N	N
	Dichlorodifluoromethane	5.0E6 (1000)		7.4E7	>1.0E5	1.5E5	>2.0E2
	Trichlorofluoromethane	5.6E6		8.4E7	N	1.7E5	N
	Carbon tetrachloride	6.0E4		9.0E5	1.0E3	1.8E3	2.0E0

		Air µg/m³ (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
Category	Compound	Health	Ecology	Health	Ecology	Health	Ecology
2A (cont'd)	1,2-Dichloroethane	2.0E5		3.0E6	1.0E4	6.0E3	2.0E1
	Trichloroethane	4.5E4 (10)		6.8E5	1.0E3	1.4E3	2.0E0
	1,2-Dichloro-1,2-difluoroethane	5.0E6 (1000)		7.4E7	N	1.5E5	N
	Hexachloroethane	1.0E4 (1)		1.5E5	N	3.0E2	N
	Dichloropropanes	3.5E5		5.3E6	1.0E3	1.1E4	2.0E0
	Bromobutanes	N		N	N	N	N
	Hexachlorocyclohexane (Lindone)	5.0E2		7.5E3	1.0E2	1.5E1	2.0E-1
	1-Chlorooctane	N		N	N	N	N
2B	Vinyl chloride (Chloroethene)	2.6E3 (1)		3.8E4	>1.0E5	7.6E1	2.0E2
	1,2-Dichloroethene	7.0E5 (200)		1.1E7	1.0E4	2.2E4	2.0E1
	1,1-Dichloroethene	2.6E5		3.9E6	1.0E4	7.8E3	2.0E1
	Tetrachloroethene	6.7E5 (100)		1.0E7	1.0E3	2.0E4	2.0E0
	Dichloropropenes	1.1E4		1.7E5	1.0E3	3.4E2	2.0E0
	Hexachlorobutadiene	4.1E3		6.1E4	N	1.2E2	N
	Hexachlorocyclopentadiene	1.1E2 (0.01)		1.7E3	N	3.4E0	N
3	Isopropyl ether	1.1E6 (250)		1.6E7	1.0E4	3.2E4	2.0E1
	2-Methoxy biphenyl	N		N	N	N	N
	2-Ethyl-4-methyl-1,3-dioxolanes	2.3E4		3.4E5	N	6.8E2	N
	1,3-Dioxane	1.8E5 (50)		2.7E6	N	5.4E3	N

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		μg/g Solid Waste (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
3 (cont'd)	1,4-Dioxane	1.8E5		2.7E6	1.0E4	5.4E3	2.0E1
4	Chloromethyl methyl ether	3.7E4		5.5E5	4.5E3	1.1E3	9.0E0
	1,1'-Dichloromethyl ether	N		N	N	N	N
	2-Chloro-1,2-epoxypropane	N		N	N	N	N
	2-Chloroethyl methyl ether	N		N	N	N	N
	1-Chloro-1,2-oxetane	N		N	N	N	N
	Chloromethyl ethyl ether	N		N	N	N	N
	Chloroethyl ethyl ether	N		N	N	N	N
	1,1'-Dichlorodiethyl ether	3.0E4 (5)		4.5E5	N	9.0E2	N
	1,2-Dichloroethyl ethyl ether	N		N	N	N	N
	2,2'-Dichlorodiethyl ether	3.0E4 (5)		4.5E5	1.0E4	9.0E2	2.0E1
	α-Chlorobutyl ethyl ether	N		N	N	N	N
	bis-(1-Chloroisopropyl) ether	N		N	N	N	N
	1,2-Dichlorodiisopropyl ether	N		N	N	N	N
	Bromophenyl phenyl ether	N		N	N	N	N
5A	Methanol	2.6E5 (200)		3.9E6	>1.0E5	7.8E3	2.0E2
	Ethanol	1.9E6 (1000)		2.9E7	>1.0E5	5.8E4	2.0E2
	1-Propanol	5.0E5		7.5E6	1.0E4	1.5E4	2.0E1
	n-Butanol	1.5E5 (50)		2.3E6	>1.0E5	4.5E3	2.0E2
	Isobutylalcohol	1.5E5 (50)		2.3E6	1.0E4	4.5E3	2.0E1
	Pentanols (primary)	3.6E5 (100)		5.4E6	1.0E4	1.1E4	2.0E1

Category	Compound	Air µg/m³ (ppm)		Water µg/ℓ (ppm)		µg/g Solid Waste (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
5A (cont'd)	α-Hydroxytoluene (Benzyl alcohol)	5.5E4		8.3E5	1.0E4	1.7E3	2.0E1
5B	2-Propanol (Isopropyl alcohol)	9.8E5 (400)		1.5E7	1.0E4	3.0E4	2.0E1
	2-Butanol	4.5E5 (150)		6.8E6	>1.0E5	1.4E4	2.0E2
	Pentanols (secondary)	3.6E5 (100)		5.4E6	N	1.1E4	N
	2,6-Dimethyl-4-heptanol	1.6E5		2.4E6	N	4.8E3	N
	1-Phenylethanol	1.8E4		2.7E5	N	5.4E2	N
	Borneol	9.0E4		1.4E6	N	2.8E3	N
5C	Tertiary butanol	3.0E5 (100)		4.5E6	>1.0E5	9.0E3	2.0E2
	Tertiary pentanol	4.5E4		6.8E5	>1.0E5	1.4E3	2.0E2
	α-Terpineol	1.9E5		2.9E6	N	5.8E3	N
	Isoborneol	N		N	N	N	N
6A	Ethylene glycol (1,2-Ethanediol)	1.0E4		1.5E5	1.0E4	3.0E2	2.0E1
	Propylene glycol (1,2-Propanediol)	3.6E5 (100)		5.4E6	>1.0E5	1.1E4	2.0E2
6B	2,3-Epoxy-1-propanol	1.5E5 (50)		2.3E6	N	5.2E3	N
	1-Chloro-2,3-epoxypropane (α-Epichlorohydrin)	1.6E4		2.4E5	1.0E3	4.8E2	2.0E0
7A	Formaldehyde	1.6E3		2.4E4	1.0E3	4.8E1	2.0E0
	Acetaldehyde	1.8E5 (100)		2.7E6	N	5.4E3	N
	Acrolein	2.5E2 (0.1)	9.4E1	3.8E3	<1.0E2	7.5E0	2.0E-1
	Propionaldehyde	3.6E4		5.4E5	1.0E4	1.1E3	2.0E1

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		µg/g Solid Waste (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
7A (cont'd)	Butyraldehyde	1.1E5		1.7E6	1.0E2	3.3E3	2.0E-1
	3-Methylbutanal	3.9E5		5.8E6	1.0E3	1.2E4	2.0E0
	Benzaldehyde	5.9E4		8.8E5	N	1.8E3	N
7B	Acetone	2.4E6 (1000)		3.6E7	>1.0E5	7.2E4	>2.0E2
	Tetrachloroacetone	N		N	N	N	N
	Butanone	5.9E5 (200)		8.9E6	>1.0E5	1.8E4	>2.0E2
	Isophorone	2.5E4		3.8E5	N	7.5E2	N
	Camphor	1.2E4 (2)		1.8E5	N	3.6E2	N
	Acetophenone	4.1E4		6.1E5	N	1.2E3	N
	Chlorohydroxy benzophenone	N		N	N	N	N
	5,6-Benzo-9-anthrone	N		N	N	N	N
	Dihydro(d)carvone	N		N	N	N	N
8A	Formic acid	9.0E3 (5)		1.4E5	N	2.7E2	N
	Acetic acid	2.5E4 (10)		3.8E5	1.0E3	7.6E2	2.0E0
	Maleic acid	1.0E3 (0.25)		1.5E4	N	3.0E1	N
	Benzoic acid	1.4E5		2.1E6	N	4.2E3	N
	Phthalic acid	6.0E3 (1)		9.0E4	N	1.8E2	N
	Long chain acids	N		N	N	N	N
8B	Hydroxyacetic acid	8.8E4		1.3E6	N	2.6E3	N
	Hydroxybenzoic acid	4.0E4		6.0E5	N	1.2E3	N
	3-Hydroxypropanoic acid lactone	3.2E2		4.8E3	1.0E4	9.6E0	2.0E1
	6-Aminohexanoic acid	N		N	N	N	N

Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
8B (cont'd)	β-Propiolactone	3.2E2		1.6E3	N	3.2E0	N
8C	Formamide	3.0E4 (20)		4.5E5	N	9.0E2	N
	Acetamide	4.5E5		6.8E6	N	1.4E4	N
	6-Hexanelactam (e-caprolactam)	1.0E3		1.5E4	N	3.0E0	N
8D	Methyl methacrylate	4.1E5 (100)		6.2E6	1.0E4	1.2E4	2.0E1
	Phthalate esters	5.0E3		7.5E4	1.5E0	1.5E2	3.0E-3
	Adipates	1.9E4		2.8E5	N	5.6E2	N
	Long chain esters	N		N	N	N	N
	Methyl benzoate	1.5E5		2.3E6	N	4.6E3	N
	Phenyl benzoate	N		N	N	N	N
	Di-2-ehtylhexyl phthalate	N		N	N	N	N
9	Acetonitrile	7.0E4 (40)		1.1E6	1.0E5	2.1E3	2.0E2
	Acrylonitrile	4.5E4 (20)		6.8E5	1.0E3	1.4E3	2.0E0
	1-Cyanoethane	1.8E3		2.7E4	N	5.4E1	N
	Butyronitrile	2.3E4		3.4E5	N	6.8E2	N
	1,3-Dicyano-1-hydroxybutane	N		N	N	N	N
	Benzonitrile	3.2E4		4.9E5	N	9.8E2	N
	Naphthonitriles	N		N	N	N	N
	Tetramethylsuccinonitrile	3.0E3 (0.5)		4.5E4	N	9.0E1	N
10A	Methylamine	1.2E3 (10)		1.8E4	1.0E3	3.6E1	2.0E0
	Ethylamine	1.8E4 (10)		2.7E5	1.0E3	5.4E2	2.0E0
	Ethanolamine	6.0E3 (3)		9.0E4	1.0E4	1.8E2	2.0E1

		Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		μg/g Solid Waste (ppm)	
Category	Compound	Health	Ecology	Health	Ecology	Health	Ecology
10A (cont'd)	1,2-Diaminoethane	2.5E4 (10)		3.8E5	1.0E3	7.6E2	2.0E0
	3-Aminopropane	N		N	N	N	N
	Propanolamine	1.3E5		1.9E6	N	3.8E3	N
	Butylamines	1.5E4 (5)		2.3E5	>1.0E5	4.5E2	2.0E2
	Cyclohexylamine	4.0E4 (10)		6.0E5	1.0E4	1.2E3	2.0E1
10B	Ethyleneimine	3.3E2		5.0E3	N	1.0E1	N
	Dimethylamine	1.8E4 (10)		2.7E5	1.0E3	5.4E2	2.0E0
	Ethylmethylamine	N		N	N	N	N
	Diethylamine	7.5E4 (25)		1.1E6	1.0E3	2.2E3	2.0E0
	Morpholine	7.0E4 (20)		1.1E6	1.0E4	2.1E3	2.0E1
10C	Aniline	1.9E4 (5)		3.0E5	1.0E3	6.0E2	2.0E0
	Aminotoluenes (Methyl anilines)	1.1E2		1.7E3	N	3.0E0	N
	Dimethylaniline (Xylidines)	2.5E4 (5)		3.8E5	N	7.5E2	N
	Anisidines	5.0E2 (0.1)		7.5E3	N	1.5E1	N
	1,4-Diaminobenzene	4.5E3		6.8E4	N	1.4E2	N
	4-Aminobiphenyl	1.3E3		2.0E4	N	4.0E1	N
	Benzidine (4,4'-Diaminobiphenyl)	1.4E4		2.1E5	1.0E2	4.2E2	2.0E-1
	3,3'-Dichlorobenzidine	6.6E3		9.9E4	N	2.0E2	N
	4,4'-Methylene-bis-(2-chloroaniline)	2.2E2		3.3E3	N	6.6E0	N

Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
10C (cont'd)	1-Aminonaphthalene	5.6E2		8.5E3	1.0E2	1.7E1	2.0E-1
	2-Aminonaphthalene	1.7E2		2.5E3	1.0E2	5.0E0	2.0E-1
10D	N,N-Dimethylaniline	2.5E4 (5)		3.8E5	N	7.5E2	N
11	Diazomethane	4.0E2 (0.2)		6.0E3	N	1.2E1	N
	Monomethylhydrazine	3.5E2 (0.2)		5.3E3	N	1.1E1	N
	N,N-Dimethylhydrazine	1.0E3 (0.5)		1.5E4	N	3.0E1	N
	N,N'-Dimethylhydrazine	3.2E1		5.0E2	N	1.0E0	N
	1,2-Diphenylhydrazine	1.4E4		2.0E5	N	4.0E2	N
	-Dimethylaminoazobenzene	2.0E3		3.0E4	N	6.0E1	N
12	N-Nitroso-dimethylamine	1.2E0		1.8E1	N	3.6E-2	N
	N-Nitroso-diethylamine	1.2E2		1.8E3	N	3.6E0	N
	N-Nitroso-dipropylamine	2.4E3		3.6E4	N	7.2E1	N
	N-Nitroso-diisopropylamine	3.8E4		5.8E5	N	1.2E3	N
	N-Nitroso-dipentylamine	N		N	N	N	N
	N-Methyl-N-nitroso-aniline	1.3E3		1.9E4	N	3.8E1	N
	N-Nitroso-diphenylamine	7.4E4		1.1E6	N	2.2E3	N
13A	Methanethiol	1.0E3 (0.5)		1.5E4	N	3.0E1	N
	Ethanethiol	1.0E3 (0.5)		1.5E4	N	3.0E1	N
	Propanethiols	8.1E4		1.2E6	N	2.4E3	N
	n-Butanethiol	1.5E3 (0.5)		2.3E4	N	4.5E1	N
	Benzenethiol	2.1E3		3.1E4	N	6.2E1	N
	1-Anthracenethiol	N		N	N	N	N

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		µg/g Solid Waste (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
13A (cont'd)	Perchloromethanethiol	8.0E2 (0.1)		1.2E4	N	2.4E1	N
13B	Dimethyl sulfide	2.4E4		3.6E5	N	7.2E2	N
	Diethyl sulfide	N		N	N	N	N
	Diphenyl sulfide	9.6E4		1.4E6	N	2.9E3	N
	Methyl disulfide	N		N	N	N	N
14A	Benzenesulfonic acid	4.0E4		6.0E5	N	1.2E3	N
	9,10-Anthraquinone-disulfonic acid	N		N	N	N	N
14B	Dimethyl sulfoxide	8.1E2		1.2E3	N	2.4E0	N
15	Benzene	3.0E3 (1)		4.5E4	1.0E3	9.0E1	2.0E0
	Toluene	3.8E5 (100)		5.6E6	1.0E3	1.1E4	2.0E0
	Ethyl benzene	4.4E5 (100)		6.5E6	1.0E3	1.3E4	2.0E0
	Styrene	4.2E5 (100)		6.3E6	1.0E3	1.3E4	2.0E0
	Propyl benzene	2.2E5		3.3E6	1.0E3	6.6E3	2.0E0
	Isopropyl benzene	6.3E4		9.5E5	1.0E3	1.9E3	2.0E0
	Indan	2.3E5		3.4E6	N	6.8E3	N
	Indene	4.5E4 (10)		6.8E5	N	1.4E0	N
	Butylbenzene	2.3E5		3.4E6	N	6.8E3	N
	Biphenyl	1.0E3 (0.2)		1.5E4	N	3.0E1	N
	4,4'-Diphenylbiphenyl	N		N	N	N	N
	Xylenes	4.4E5 (100)		6.5E6	1.0E3	1.3E4	2.0E0
	Dialkyl benzenes	2.3E5		3.4E6	1.0E3	6.8E3	2.0E0

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		Solid Waste μg/ (pp	
		Health	Ecology	Health	Ecology	Health	Ecolog
15 (cont'd)	Tetrahydronaphthalene	1.3E5		2.0E6	1.0E3	4.0E3	2.0E0
	Dihydronaphthalene	1.3E5		2.0E6	N	4.0E3	N
	Terphenyls	9.0E3 (1)		1.4E5	N	2.8E2	N
	Trimethylbenzenes	1.2E5 (25)		1.8E6	N	3.6E3	N
	Tetramethylbenzenes	N		N	1.0E4	N	2.0E1
16A	Chlorobenzene	3.5E5 (75)		5.3E6	1.0E2	1.1E4	2.0E-
	Bromo and Dibromobenzenes	N		N	N	N	N
	Bromochlorobenzenes	N		N	N	N	N
	1,2-Dichlorobenzene	3.0E5 (50)		4.5E6	1.0E2	9.0E3	2.0E-
	1,3-Dichlorobenzene	N		N	N	N	N
	1,4-Dichlorobenzene	4.5E5 (75)		6.8E6	1.0E2	1.4E4	2.0E-
	Polychlorinated benzenes	3.4E4		5.1E5	1.0E2	1.0E3	2.0E-
	2-Chlorotoluene	2.5E5 (50)		3.8E6	N	7.5E3	N
	Chloronaphthalenes	6.9E4		1.0E6	N	1.5E1	1.0E-
	Polychlorinated biphenyls	5.0E2		7.5E3	5.0E-3		
16B	-Chlorotoluene	5.0E3		7.5E4	1.0E2	1.5E0	2.0E-
	Bis-(Chloromethyl)benzene	N		N	N	N	N
17	Nitrobenzene	5.0E3 (1)		7.5E4	1.0E3	1.5E2	2.0E0
	4-Nitrobiphenyl	1.3E3		2.0E4	N	4.0E1	N
	1-Chloro-2-nitrobenzene	1.3E4		2.0E5	1.0E4	4.0E2	2.0E1
	1-Chloro-4-nitrobenzene	1.9E4		2.9E5	N	5.8E2	N
	Methoxynitrobenzenes	4.5E3		6.8E4	N	1.4E2	N

		Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		$\mu g/g$ Solid Waste (ppm)	
Category	Compound	Health	Ecology	Health	Ecology	Health	Ecology
17 (cont'd)	Nitrotoluenes	3.0E4 (5)		4.5E5	1.0E3	9.0E2	2.0E0
	Dinitrotoluenes	1.5E3		2.3E4	1.0E3	4.5E1	2.0E0
18A	Phenol	1.9E4 (5)		5.0E0	5.0E2	1.0E-2	1.0E0
	Cresols (Methyl phenols)	2.2E4 (5)		5.0E0	5.0E2	1.0E-2	1.0E0
	2-Methoxyphenol	3.3E4		5.0E0	5.0E2	1.0E-2	1.0E0
	Ethylphenols	N		5.0E0	5.0E2	1.0E-2	1.0E0
	Phenylphenols	2.3E4		5.0E0	5.0E2	1.0E-2	1.0E0
	2,2'-Dihydroxydiphenyls	6.8E3		5.0E0	5.0E2	1.0E-2	1.0E0
	Xylenols (Dimethyl phenols)	1.3E4		5.0E0	5.0E2	1.0E-2	1.0E0
	Alkyl cresols	2.4E4		5.0E0	5.0E2	1.0E-2	1.0E0
	Polyalkyl phenols	1.5E4		5.0E0	5.0E2	1.0E-2	1.0E0
18B	Catechol (1,2-Dihydroxybenzene)	2.0E4 (5)		5.0E0	5.0E2	1.0E-2	1.0E0
	1,3-Dihydroxybenzene	4.5E4 (10)		5.0E0	5.0E2	1.0E-2	1.0E0
	1,4-Dihydroxybenzene	2.0E3		5.0E0	5.0E2	1.0E-2	1.0E0
	1,2,3-Trihydroxybenzenes	3.6E4		5.0E0	5.0E2	1.0E-2	1.0E0
18C	1-Naphthol	1.2E5		5.0E0	5.0E2	1.0E-2	1.0E0
	2-Naphthol	1.1E5		5.0E0	5.0E2	1.0E-2	1.0E0
	Phenanthrols	N		5.0E0	5.0E2	1.0E-2	1.0E0
	Indanols	1.5E5		5.0E0	5.0E2	1.0E-2	1.0E0
	Acenaphthols	N		5.0E0	5.0E2	1.0E-2	1.0E0
	2-Hydroxyfluorene	N		5.0E0	5.0E2	1.0E-2	1.0E0
	2-Hydroxydibenzofuran	N		5.0E0	5.0E2	1.0E-2	1.0E0
19	2-Chlorophenol	3.0E4		5.0E0	5.0E2	1.0E-2	1.0E0
	2,4-Dichlorophenol	7.0E3		5.0E0	5.0E2	1.0E-2	1.0E0

		Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
Category	Compound	Health	Ecology	Health	Ecology	Health	Ecology
19 (cont'd)	Penthachlorophenol	5.0E2		5.0E0	5.0E2	1.0E-2	1.0E0
	Chlorinated cresols	2.3E4		5.0E0	5.0E2	1.0E-2	1.0E0
20	2-Nitrophenol	5.8E4		5.0E0	5.0E2	1.0E-2	1.0E0
	3-Nitrophenol	2.0E4		5.0E0	5.0E2	1.0E-2	1.0E0
	4-Nitrophenol	1.6E4		5.0E0	5.0E2	1.0E-2	1.0E0
	Dinitrophenols	1.4E3		5.0E0	5.0E2	1.0E-2	1.0E0
	4,6-Dinitro-o-cresol	2.0E2 (0.025)		5.0E0	5.0E2	1.0E-2	1.0E0
	Dinitro-p-cresol	6.8E2		5.0E0	5.0E2	1.0E-2	1.0E0
	2-Amino-4,6-dinitrophenol	4.6E4		5.0E0	5.0E2	1.0E-2	1.0E0
	2,4,6-Trinitrophenol	1.0E2 (0.011)		5.0E0	5.0E2	1.0E-2	1.0E0
21	Naphthalene	5.0E4		7.5E5	1.0E2	1.5E3	2.0E-1
	Monoalkyl naphthalenes	2.3E5		3.4E6	N	6.8E3	N
	Phenyl naphthalenes	N		N	N	N	N
	Dimethyl naphthalenes	2.3E5		3.4E6	N	6.8E3	N
	Acenaphthene	N		N	N	N	N
	Acenaphthylene	N.		N	N	N	N
	Anthracene	5.6E4		8.4E5	N	1.7E3	N
	2,7-Dimethylanthracene	N		N	N	N	N
	Phenanthrene	1.6E3		2.4E4	N	4.8E1	N
	Methylphenanthrenes	3.0E4		4.6E5	N	9.1E2	N
	Naphthacene	N		N	N	N	N
	Benz(a)anthracene	4.5E1		6.7E2	N	1.3E0	N
	7,12-Dimethylbenz(a)-anthracene	2.6E-1		3.9E0	N	8.0E-3	N
	Benzo(c)phenanthrene	2.7E4		4.1E5	N	8.2E2	N
	Chrysene	2.2E3		3.3E4	N	6.6E1	N

Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
21 (cont'd)	Methyl chrysenes	1.8E3		2.7E4	N	5.4E1	N
	Triphenylene	N		N	N	N	N
	Pyrene	2.3E5		3.5E6	N	6.9E3	N
	1-Methylpyrene	N		N	N	N	N
	Dimethyl pyrenes	N		N	N	N	N
	1,2-Benzonaphthacene	N		N	N	N	N
	Benzo(g)chrysene	1.6E4		2.4E5	N	4.8E2	N
	Dibenz(a,c)anthracene	9.9E3		1.5E5	N	3.0E2	N
	Dibenz(a,h)anthracene	9.3E-2		1.4E0	N	3.0E-3	N
	Benzo(a)pyrene	2.0E-2		3.0E-1	N	6.0E-2	N
	Benzo(e)pyrene	3.0E3		4.6E4	N	9.1E1	N
	Perylene	N		N	N	N	N
	Picene	2.5E3		3.8E4	N	7.5E1	N
	Dibenzo(a,h)pyrene	3.7E3		5.6E4	N	1.1E2	N
	Dibenzo(a,i)pyrene	4.3E1		6.5E2	N	1.3E0	N
	Dibenzo(a,)pyrene	1.1E3		1.6E4	N	3.2E1	N
	Benzo(g,h,i)perylene	N		N	N	N	N
	Coronene	N		N	N	N	N
22	Dicyclopentadiene	1.6E4		2.4E5	1.0E2	4.8E2	2.0E-1
	Fluorene	N		N	N	N	N
	Cyclopentanonaphthalene	N		N	N	N	N
	2,3-Benzofluorene	N		N	N	N	N
	Fluoranthene	9.0E4		1.4E6	N	2.8E3	N
	1,2-Benzofluorene	N		N	N	N	N
	Cyclopenta(def)phenanthrene	N		N	N	N	N
	Benzo(k)fluoranthene	1.6E3		2.5E4	N	4.9E1	N

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		μg/g Solid Waste (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
22 (cont'd)	Benzo(e)fluoranthene	9.0E2		1.4E4	N	2.8E1	N
	Benzo(j)fluoranthene	6.5E3		9.8E4	N	2.0E2	N
	1,2:5,6-Dibenzofluorene	1.3E4		2.0E5	N	4.0E2	N
	Benzo(b)fluoranthene	9.0E2		1.3E4	N	2.7E1	N
	3-Methyl-cholanthrene	3.8E0		5.6E1	N	1.1E-1	N
	Indeno(1,2,3,cd)pyrene	1.6E3		2.4E4	N	4.8E1	N
	Tribenzylenebenzene (Truxene)	N		N	N	N	N
23A	Pyridine	1.5E4 (5)		2.3E5	1.0E4	4.5E2	2.0E1
	Picolines	3.6E4		5.3E5	N	1.1E3	N
	Monosubstituted alkyl pyridines	N		N	N	N	N
	Phenyl pyridines	N		N	N	N	N
	Chloropyridine	4.8E3		7.2E4	N	1.4E2	N
	Collidines	6.9E4		1.0E6	N	2.1E3	N
	Di and Polysubstituted pyridines	2.7E4		4.1E5	N	8.2E2	N
23B	Quinoline; Isoquinoline	1.6E4		2.4E5	N	4.7E2	N
	2-Methylquinoline	5.5E4		8.3E5	N	1.7E3	N
	Dimethylquinolines, Dimethyl-isoquinolines	N		N	N	N	N
	Acridine	9.0E4		1.4E6	N	2.7E3	N
	Dihydroacridine	N		N	N	N	N
	Benzo(c)quinoline	N		N	N	N	N
	Benzo(f)quinoline	N		N	N	N	N

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
23B (cont'd)	Benzo(h)quinoline	N		N	N	N	N
	Benz(a)acridine	N		N	N	N	N
	Benz(c)acridine	1.1E4		1.6E5	N	3.2E2	N
	Dibenz(a,j)acridine	2.5E2		3.7E3	N	7.4E0	N
	Dibenz(a,h)acridine	2.2E2		3.4E3	N	6.7E0	N
	Dibenz(c,h)acridine	2.3E4		3.5E5	N	6.9E2	N
	2,3-Benz-4-azafluorene	N		N	N	N	N
	Indeno(1,2,3-ij)isoquinoline	N		N	N	N	N
23C	Pyrrole	2.7E3		4.0E4	N	8.1E1	N
	Indole	1.1E4		1.7E5	N	3.3E2	N
	Methylindoles	4.5E4		6.8E5	N	1.4E3	N
	Carbazole	2.3E4		3.4E5	N	6.8E2	N
	Benzo(a)carbazole	1.9E4		2.8E5	N	5.6E2	N
	Dibenzo(a,i)carbazole	1.2E4		1.8E5	N	3.6E2	N
	Dibenzo(c,d)carbazole	1.0E3		1.5E3	N	3.0E0	N
	Dibenzo(a,g)carbazole	6.0E3		9.0E4	N	1.8E2	N
23D	Benzothiazole	4.3E3		6.4E4	N	1.3E2	N
	Methyl benzothiazoles	4.7E3		7.1E4	N	1.4E2	N
24	Furan	N		N	N	N	N
	Benzofuran	N		N	N	N	N
	Dibenzofuran	N		N	N	N	N
	Methyldibenzofurans	N		N	N	N	N
	Naphthofurans	N		N	N	N	N
	Benzo(b)naphtho(2,3-d)furan	N		N	N	N	N
	Phenanthro(9,10-b)furan	N		N	N	N	N

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		Solid Waste μg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
24 (cont'd)	1,9-Benzoxanthene	N		N	N	N	N
	Tetrahydrofuran	5.9E5 (200)		9.0E6	N	1.8E4	N
25	Thiophene	4.5E3		6.8E4	N	1.4E2	N
	Methylthiophenes	2.3E4		3.4E5	N	7.0E2	N
	Dimethylthiophenes	N		N	N	N	N
	Tri and Tetramethyl thiophenes	N		N	N	N	N
	2,2-Bithiophene	N		N	N	N	N
	Benzo(b)thiophene	2.3E4		3.5E5	N	7.0E2	N
	Dibenzothiophene	N		N	N	N	N
	Benzonaphthothiophene	9.9E2		1.5E4	N	3.0E1	N
26A	Trimethylarsine	N		N	N	N	N
	Tetramethyllead	1.5E2 (0.014)		2.3E3	N	4.5E0	N
	Tetraethyllead	1.0E2 (0.0075)		1.5E3	<1.0E2	3.0E0	2.0E-1
	Alkyl mercury	1.0E1 (0.001)		1.5E2	2.0E-2	3.0E-1	4.0E-5
	Organotin	1.0E2		1.5E3	N	3.0E0	N
	Organogermanes	3.2E4		4.7E5	N	9.4E2	N
	Alkyl stibines	N		N	N	N	N
26B	Ferrocene	6.0E4		9.0E5	N	1.8E3	N
	Nickelocene	3.5E3		5.2E4	N	1.0E2	N
	Dibenze chromium	N		N	N	N	N
26C	Complexed nickel	N		N	N	N	N
	Complexed copper	3.0E3		4.5E4	N	9.0E1	N
	Complexed iron	N		N	N	N	N
	Complexed tin	N		N	N	N	N
	Complexed zinc	N		N	N	N	N

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		Solid Waste μg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
27	Lithium, Li	2.2E1	N	3.3E2	3.8E2	7.0E-1	7.5E-1
	Lithium Ion, Li^+	2.2E1	N	3.3E2	3.8E2	7.0E-1	7.5E-1
	Lithium Fluoride, LiF (as Li)	2.2E1	N	3.3E2	3.8E2	7.0E-1	7.5E-1
	Lithium Carbonate, Li_2CO_3 (as Li)	2.2E1	N	3.3E2	3.8E2	7.0E-1	7.5E-1
	Lithium Hydride, LiH	2.5E1	N	3.8E2	N	7.5E-1	N
28	Sodium, Na	5.3E4	N	8.0E5	N	1.6E3	N
	Sodium Ion, Na^+	5.3E4	N	8.0E5	N	1.6E3	N
	Sodium Hydroxide, NaOH	2.0E3	N	3.0E4	N	6.0E1	N
29	Potassium, K	N	N	N	N	N	N
	Potassium Ion, K^+ (as K)	N	N	N	2.3E4	N	4.6E1
	Potassium Hydroxide, KOH	2.0E3	N	3.0E4	N	6.0E1	N
30	Rubidium Ion, Rb^+	1.2E5	N	1.8E6	N	3.6E3	N
31	Cesium Ion, Ce^+	8.2E4	N	1.2E6	N	2.5E3	N
32	Beryllium, Be	2.0E0	N	3.0E1	5.5E1	6.0E-2	1.1E-1
	Beryllium Ion, Be^{++}	2.0E0	N	3.0E1	5.5E1	6.0E-2	1.1E-1
	Beryllium Oxide, BeO (as Be)	2.0E0	N	3.0E1	5.5E1	6.0E-2	1.1E-1
	Beryl, $BeO\cdot Al_2O_3\cdot SiO_2$ (as Be)	2.0E0	N	3.0E1	5.5E1	6.0E-2	1.1E-1
33	Magnesium, Mg	6.0E3	N	9.0E4	8.7E4	1.8E2	1.7E2
	Magnesium Ion, Mg^{++}	6.0E3	N	9.0E4	8.7E4	1.8E2	1.7E2
	Magnesium Oxide, MgO	1.0E4	N	1.5E5	1.0E5	3.0E2	2.0E2

Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
33 (cont'd)	Magnesium Fluoride, MgF_2 (as Mg)	6.0E3	N	9.0E4	8.7E4	1.8E2	1.7E2
	Magnesium Sulfate, $MgSO_4$ (as Mg)	6.0E3	N	9.0E4	8.7E4	1.8E2	1.7E2
	Magnesite, $MgCO_3$ (as Mg)	6.0E3	N	9.0E4	8.7E4	1.8E2	1.7E2
	Dolomite, $MgCO_3 \cdot CaCO_3$ (as Mg)	6.0E3	N	9.0E4	8.7E4	1.8E2	1.7E2
	Asbestos (as Mg)	6.0E3	N	9.0E4	8.7E4	1.8E2	1.7E2
34	Calcium Ion, Ca^{++}	1.6E4	N	2.4E5	1.6E4	4.8E2	3.2E1
	Calcium Fluoride, CaF_2	N	N	N	N	N	N
	Calcium Carbonate, $CaDO_3$	N	N	N	N	N	N
	Calcium Sulfate, $CaSO_4$	N	N	N	N	N	N
	Dolomite, $MgCO_3 \cdot CaCO_3$	N	N	N	N	N	N
35	Strontium	3.1E3	N	4.6E4	N	9.2E1	N
	Strontium Ion, Sr^{++} (as Sr)	3.1E3	N	4.6E4	N	9.2E1	N
	Strontium Fluoride, SrF_2 (as Sr)	3.1E3	N	4.6E4	N	9.2E1	N
	Strontium Sulfate, $SrSO_4$ (as Sr)	3.1E3	N	4.6E4	N	9.2E1	N
36	Barium, Ba	5.0E2	N	5.0E3	2.5E3	1.0E1	5.0E0
	Barium Ion, Ba^{++} (as Ba)	5.0E2	N	5.0E3	2.5E3	1.0E1	5.0E0
	Barium Sulfide, BaS (as Ba)	5.0E2	N	5.0E3	2.5E3	1.0E1	5.0E0
	Barium Thiocarbonate, $BaCS_3$ (as Ba)	5.0E2	N	5.0E3	2.5E3	1.0E1	5.0E0

		Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
Category	Compound	Health	Ecology	Health	Ecology	Health	Ecology
36 (cont'd)	Barium Fluoride, BaF_2 (as Ba)	5.0E2	N	5.0E3	2.5E3	1.0E1	5.0E0
	Barium Carbonate, $BaCO_3$ (as Ba)	5.0E2	N	5.0E3	2.5E3	1.0E1	5.0E0
	Barium Sulfate, $BaSO_4$ (as Ba)	5.0E2	N	5.0E3	2.5E3	1.0E1	5.0E0
37	Baron, B	3.1E3	N	4.7E4	2.5E4	9.3E1	5.0E1
	Borate, BO_3 (as B)	3.1E3	N	4.7E4	2.5E4	9.3E1	5.0E1
	Metaborate, Bo_2- (as B)	3.1E3	N	4.7E4	2.5E4	9.3E1	5.0E1
	Boron Oxide, B_2O_3	1.0E4	N	1.5E5	N	3.0E2	N
38	Aluminum, Al	5.2E3	N	8.0E4	1.0E3	1.6E2	2.0E0
	Aluminum Ion, Al^{+++}	5.2E3	N	8.0E4	1.0E3	1.6E2	2.0E0
	Aluminum Oxide, Al_2O_3	1.0E4	N	1.5E5	N	3.0E2	N
	Bauxite, $Al_2O_3 \cdot 3H_2O$ (as Al)	5.2E3	N	8.0E4	1.0E3	1.6E2	2.0E0
	Hydrated Aluminum Silicate (as Al)	5.2E3	N	8.0E4	1.0E3	1.6E2	2.0E0
	Alums $[M\ Al\ (SO_4)_2] \cdot (H_2O)_X$ (as Al)	5.2E3	N	8.0E4	1.0E3	1.6E2	2.0E0
39	Gallium, Ga	5.0E3	N	7.4E4	N	1.5E2	N
	Elemental Species, Ga	5.0E3	N	7.4E4	N	1.5E2	N
	Gallous, Ga^{+1} (as Ga)	5.0E3	N	7.4E4	N	1.5E2	N
	Gallic, Ga^{+3} (as Ga)	5.0E3	N	7.4E4	N	1.5E2	N
	Gallium Sesquioxide, Ga_2O_3 (as Ga)	5.0E3	N	7.4E4	N	1.5E2	N

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
40	Indium, In	1.0E2	N	1.5E3	N	3.0E0	N
	Indium Ion, In^{+3}	1.0E2	N	1.5E3	N	3.0E0	N
41	Thallium, Tl	1.0E2	N	1.5E3	N	3.0E0	N
	Thallous, Tl^{+1}	1.0E2	N	1.5E3	N	3.0E0	N
	Thallic, Tl^{+3}	1.0E2	N	1.5E3	N	3.0E0	N
42	Elemental Carbon	3.5E3	N	5.3E4	N	1.6E2	N
	Coal	N	N	N	N	N	N
	Carbide, C-	N	N	N	N	N	N
	Carbonate, CO_3^{-2}	N	N	N	N	N	N
	Bicarbonate, HCO_3^-	N	N	N	N	N	N
	Carbonyl, CO=	N	N	N	N	N	N
	Carbon Monoxide	4.0E4 (35)	1.2E5 (100)	6.0E5	6.0E1	N/A	N/A
	Carbon Dioxide	9.0E6 (5000)	N	N	N	N/A	N/A
43	Silicon, Si	1.0E4	N	1.5E5	N	3.0E2	N
	Orthosilicate, SiO_4^{-2}	N	N	N	N	N	N
	Metasilicate, SiO_3^{-2}	N	N	N	N	N	N
	Silane, SiH_4	7.0E2	K	1.1E4	N	2.1E1	N
	Silicon Dioxide, SiO_2	1.0E4	N	1.5E5	N	3.0E2	N
	Silicon Disulfide, SiS_2	N	N	N	N	N	N
	Silicon Carbide, SiC	1.0E4	N	1.5E5	N	3.0E2	N

		Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		Solid Waste μg/g (ppm)	
Category	Compound	Health	Ecology	Health	Ecology	Health	Ecology
44	Germanium, Ge	5.6E2	N	8.4E3	N	1.7E1	N
	Germanous, Ge^{+2} (as Ge)	5.6E2	N	8.4E3	N	1.7E1	N
	Germanic, Ge^{+4} (as Ge)	5.6E2	N	8.4E3	N	1.7E1	N
	Germanous Sulfide, GeS (as Ge)	5.6E2	N	8.4E3	N	1.7E1	N
	Germanic Sulfide, GeS$_2$ (as Ge)	5.6E2	N	8.4E3	N	1.7E1	N
	Germane, GeH$_4$ (as Ge)	5.6E2	N	8.4E3	N	1.7E1	N
	Germanium Oxide, GeO$_2$ (as Ge)	5.6E2	N	8.4E3	N	1.7E1	N
45	Tin, Sn	N	N	N	N	N	N
	Stannous, Sn^{+2}	N	N	N	N	N	N
	Stannic, Sn^{+4}	N	N	N	N	N	N
	Tin Oxide, SnO$_2$	1.0E4	N	1.5E5	N	3.0E0	N
46	Lead, Pb	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Elemental Lead, Pb	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Plumbous, Pb^{+2}	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Plumbic, Pb^{+4} (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Lead Monoxide, PbO (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Lead Sulfate, PbSO$_4$ (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Lead Sulfide, Pbs (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Lead Carbonate, PbCO$_3$ (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Lead Phosphate, Pb$_3$(PO$_4$)$_2$ (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1

Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
46 (cont'd)	Lead Chromate, $PbCrO_4$ (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Lead Molybdate, $PbMoO_4$ (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Lead Arsenate, $PbHAsO_4$ (as Pb)	1.5E2	N	2.5E2	5.0E1	5.0E-1	1.0E-1
47	Nitride, $N\equiv$	N	N	N	N	N	N
	Nitrate, No_3^-	N	N	N	N	N	N
	Nitrite, No_2^-	N	N	N	N	N	N
	Ammonium, NH_4^+	N	N	N	N	N	N
	Nitrogen Oxides, N_2O, NO_2, N_2O_4, N_2O_3, N_2O_5	9.0E3	N	1.4E5	N	N/A	N/A
	Ammonia, NH_3	1.8E4 (25)	3.5E2	2.5E3	5.0E1	5.0E0	1.0E-1
	Hydrazine	1.5E2 (0.1)	N	2.3E0	N	4.5E0	N
	Hydrogen Cyanide, HCN	1.1E4 (10)	3.4E4	5.0E2	2.5E1	1.0E0	5.0E-2
	Alkali Cyanides, NaCN, KCN	5.0E3	N	5.0E2	2.5E1	1.0E0	5.0E-2
	Cyanogen, C_2N_2	2.0E4	1.0E3	1.0E3	2.5E1	2.0E0	5.0E-2
	Nitric Acid, HNO_3	5.0E3	N	7.5E4	4.5E2	1.5E3	9.0E-1
48	Phosphorus, P	1.0E2	N	1.5E4	5.0E-1	3.0E1	1.0E-3
	Phosphate, PO_4^{-3}	N	N	N	N	N	N
	Phosphite, PO_3^{-3} (as P)	1.0E2	N	1.5E4	5.0E-1	3.0E1	1.0E-3

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
48 (cont'd)	Biphosphate, $H_2PO_4^-$ (as P)	1.0E2	N	1.5E4	5.0E-1	3.0E1	1.0E-3
	Phosphine, PH_3	4.0E2 (0.3)	N	6.0E3	N	N/A	N/A
	Phosphoric Acid, H_3PO_4	1.0E3	N	1.5E4	4.5E3	3.0E1	9.0E
	Phosphorus Pentasulfide	1.0E3	N	1.5E4	N	3.0E1	N
49	Arsenic, As	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Metallic Arsenic	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Arsenous, As^{+3}	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Arsenic, As^{+5}	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Arsenate, AsO_4^{-3} (as As)	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Arsenite, AsO_3^{-3} (as As)	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Arsenide, As^{-3} (as As)	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Arsine, AsH_3	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
	Arsenic Trioxide, As_2O_3	2.0E0	N	2.5E2	5.0E1	5.0E-1	1.0E-1
50	Antimony, Sb	5.0E2	N	7.5E3	2.0E2	1.5E1	4.0E-1
	Antimony Metal, Sb	5.0E2	N	7.5E3	2.0E2	1.5E1	4.0E-1
	Antimonous, (stibnous) Sb^{+3}	5.0E2	N	7.5E3	2.0E2	1.5E1	4.0E-1
	Antimonic (stibnic) Sb^{+5}	5.0E2	N	7.5E3	2.0E2	1.5E1	4.0E-1
	Stibine, SbH_3 (as Sb)	5.0E2	N	7.5E3	2.0E2	1.5E1	4.0E-1
	Antimonous Sulfide, Sb_2S_3	5.0E2	N	7.5E3	2.0E2	1.5E1	4.0E-1
	Antimony Trioxide, Sb_2O_3	5.0E1	N	7.5E2	2.0E2 (as Sb)	1.5E0	4.0E-1 (as Sb)

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		Solid Waste μg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
51	Bismuth, Bi	4.1E2	N	6.1E3	N	1.2E1	N
	Elemental Bismuth, Bi	4.1E2	N	6.1E3	N	1.2E1	N
	Bismuthous, Bi^{+3} (as Bi)	4.1E2	N	6.1E3	N	1.2E1	N
	Bismuthic, Bi^{+5} (as Bi)	4.1E2	N	6.1E3	N	1.2E1	N
52	Ozone, O_3	2.0E2 (0.1)	1.0E1	N/A	N/A	N/A	N/A
53	Rhombic Sulfur, S_8	N	N	N	N	N	N
	Sulfide, S^{-2}	N	N	N	N	N	N
	Sulfate, SO_4^{-2}	N	N	N	N	N	N
	Sulfite, SO_3^{-2}	N	N	N	N	N	N
	Thiocyanate, SCN^-	N	N	N	N	N	N
	Sulfur Dioxides, SO_2	1.3E4	N	2.0E5	N	4.0E2	N
	Sulfur Trioxide, SO_3	N	N	N	N	N	N
	Carbonyl Sulfide, COS	4.4E5	N	N/A	N/A	N/A	N/A
	Hydrogen Sulfide, H_2S	1.5E4 (10)	N	2.3E4	1.0E1	N/A	N/A
	Carbon Disulfide, CS_2	6.0E4 (20)	N	9.0E5	1.0E4	N/A	N/A
	Sulfuric Acid, H_2SO_4	1.0E3	N	1.5E4	4.5E2	3.0E1	9.0E2
54	Selenium, Se	2.0E2	N	5.0E1	2.5E1	1.0E-1	5.0E-2
	Elemental Selenium, Se	2.0E2	N	5.0E1	2.5E1	1.0E-1	5.0E-2
	Selenide, Se^{-2}	2.0E2	N	5.0E1	2.5E1	1.0E-1	5.0E-2

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
54 (cont'd)	Selenites, SeO_3^{-2} (as Se)	2.0E2	N	5.0E1	2.5E1	1.0E-1	5.0E-2
	Selenates, SeO_4^{-2} (as Se)	2.0E2	N	5.0E1	2.5E1	1.0E-1	5.0E-2
	Hydrogen Selenide, H_2Se	2.0E2 (.05)	N	5.0E1 (as Se)	2.5E1 (as Se)	1.0E-1 (as Se)	5.0E-2 (as Se)
	Carbon Diselenide, CSe_2 (as Se)	2.0E2	N	5.0E1	2.5E1	1.0E-1	5.0E-2
	Selenium Dioxide, SeO_2 (as Se)	2.0E2	N	5.0E1	2.5E1	1.0E-1	5.0E-2
55	Tellurium, Te	1.0E2	N	1.5E3	N	3.0E0	N
	Telluride, Te^{-2}	1.0E2	N	1.5E3	N	3.0E0	N
	Tellurite, TeO_3^{-2} (as Te)	1.0E2	N	1.5E3	N	3.0E0	N
	Tellurate, TeO_4 (as Te)	1.0E2	N	1.5E3	N	3.0E0	N
56	Fluoride Ion, F^-	2.5E3	N	3.8E4	N	7.5E1	N
	Hydrogen Fluoride, HF	2.0E3	N	3.0E4	N	N/A	N/A
57	Chloride Ion, Cl^-	N	N	1.3E6	N	2.6E3	N
	Hypochlorite, ClO^-	N	N	N	N	N	N
	Chlorite, ClO_2^-	N	N	N	N	N	N
	Chlorate, ClO_3	N	N	N	N	N	N
	Hydrogen Chloride, HCl	7.0E3	N	1.1E5	N	N/A	N/A
	Chlorine Dioxide, ClO_2	N	N	N	N	N	N
	Carbonyl Chloride (phosgene), $COCl_2$	4.0E2	N	6.0E3	N	N/A	N/A
58	Bromide Ion, Br^-	N	N	N	N	N	N

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
58 (cont'd)	Bromide Ion, Br$^-$	N	N	N	N	N	N
	Hydrogen Bromide, HBr	1.0E4	N	1.5E5	N	N/A	N/A
59	Iodide Ion, I$^-$	N	N	N	N	N	N
60	Scandium, Sc	5.3E4	N	8.0E5	N	1.6E3	N
	Scandium Ion, Sc^{+3}	5.3E4	N	8.0E5	N	1.6E3	N
61	Yttrium Ion, Y^{+3}	1.0E3	N	1.5E4	N	3.0E1	N
62	Titanium, Ti	6.0E3	N	9.0E4	8.2E2 (as Ti [SO$_4$]$_2$)	1.8E2	1.6E0
	Titanous, Ti^{+3} (as Ti)	6.0E3	N	9.0E4	8.2E2	1.8E2	1.6E0
	Titanic, Ti^{+4} (as Ti)	6.0E3	N	9.0E4	8.2E2	1.8E2	1.6E0
	Titanium Dioxide, TiO$_2$ (as Ti)	6.0E3	N	9.0E4	8.2E2	1.8E2	1.6E0
63	Zirconium Ion, Zr^{+4}	5.0E3	N	7.5E4	N	1.5E1	N
	Zirconium Dioxide, ZrO$_2$ (as Zr)	5.0E3	N	7.5E4	N	1.5E1	N
64	Hafnium Ion, Hf^{+4}	5.0E2	N	7.5E4	N	1.5E0	N
65	Vanadium, V	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Elemental Vanadium, V	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadic, V^{+3} (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadyl, Vo^{+2} (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Orthovanadate, Vo$_4^{-4}$ (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Metavanadate, VO$_3^-$ (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
65 (cont'd)	Vanadylic, VO^{+3} (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadium Monoxide, VO (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadium Trioxide, V_2O_3 (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadium Tetraoxide, V_2O_4, (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadium Pentoxide, V_2O_5 (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadium Carbide, VC (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadium Monosulfide, VS (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadium Nitride, VN (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
	Vanadyl Sulfate, $VOSO_4 \cdot 5H_2O$ (as V)	5.0E2	1.0E0	2.5E3	1.5E2	5.0E0	3.0E-1
66	Niobus, Nb^{+3}	2.2E4	N	3.3E5	N	6.5E2	N
	Niobic, Nb^{+5}	2.2E4	N	3.3E5	N	6.5E2	N
	Niobium Oxides, NbO, Nb_2O_5 (as Nb)	2.2E4	N	3.3E5	N	6.5E2	N
67	Tantalum Ion, Ta^{+5}	5.0E3	N	7.5E4	N	1.5E2	N
68	Chromium, Cr	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Chromous, Cr^{+2} (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Chromic, Cr^{+3} (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		Solid Waste μg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
68 (cont'd)	Chromates, CrO_4^{-2} (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Chromites, $Cr_2O_4^{-2}$ (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Dichromates, $Cr_2O_7^{-2}$ (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Chromium Carbonyl, $Cr(CO)_6$ (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Chromium Sulfide, Cr_2S_3	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Chromic Oxide, Cr_2O_3 (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Chromite Mineral, FeO Cr_2O_3 (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Hydrous Chromium Phosphate, $CrPO_4$ XH_2O (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
	Iron Chromate, $FeCrO_4$ (as Cr)	1.0E0	N	2.5E2	2.5E2	5.0E-1	5.0E-1
69	Molybdenum, Mo	5.0E3	N	7.5E4	7.0E3	1.5E2	1.4E1
	Molybdenous, Mo^{+2}	5.0E3	N	7.5E4	7.0E3	1.5E2	1.4E1
	Molybdic, Mo^{+3}	5.0E3	N	7.5E4	7.0E3	1.5E2	1.4E1
	Molybdate, MoO_4^{-2} (as Mo)	5.0E3	N	7.5E4	7.0E3	1.5E2	1.4E1
	Molybdenum Sulfide, MoS_2 (as Mo)	5.0E3	N	7.5E4	7.0E3	1.5E2	1.4E1
	Molybdenum Trioxide, MoO_3 (as Mo)	5.0E3	N	7.5E4	7.0E3	1.5E2	1.4E1
70	Tungsten, W	1.0E3	N	1.5E4	N	3.0E1	N
	Tungsten Ions, W^{+2}, W^{+4}, W^{+5}, W^{+6}, WO_4^{-2}	N	N	N	N	N	N

Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
70 (cont'd)	Tungsten Disulfide, WS_2 (as W)	1.0E3	N	1.5E4	N	3.0E1	N
	Wolframite Mineral, $FeWO_4 \cdot MnWO_4$ (as W)	1.0E3	N	1.5E4	N	3.0E1	N
71	Manganese, Mn	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
	Manganous, Mn^{+2}	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
	Manganic, Mn^{+3}	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
	Permanganate, MnO_4^- (as Mn)	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
	Manganous Oxide, MnO (as Mn)	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
	Manganese Dioxide, MnO_2 (as Mn)	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
	Manganese Carbonate, $McCO_3$ (as Mn)	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
	Manganous Sulfate, $MnSO_4$ (as Mn)	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
	Manganese Sulfide, MnS_2 (as Mn)	5.0E3	N	2.5E2	1.0E2	5.0E-1	2.0E-1
72	Ferrous, Fe^{+2}	1.0E3	N	1.5E3	2.5E2	3.0E0	5.0E-1
	Ferric, Fe^{+3}	1.0E3	N	1.5E3	2.5E2	3.0E0	5.0E-1
	Ferrocyanide, $Fe(CN)_6^{-4}$	N	N	N	N	N	N
	Ferricyanide, $Fe(CN)_6^{-3}$	N	N	N	N	N	N
	Ferrous Oxide, FeO	5.0E3	N	7.5E4	N	1.5E2	N
	Ferric Oxide, Fe_2O_3	N	N	N	>1.0E5	N	2.0E2
	Ferric Hydroxide (hydrated) $Fe_2O_3 \cdot XH_2O$	N	N	N	N	N	N

Category	Compound	Air μg/m^3 (ppm)		Water μg/ℓ (ppm)		Solid Waste μg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
72 (cont'd)	Iron Sulfides, FeS, Fe_2S_3	N	N	N	N	N	N
	Pyrite, FeS_2	N	N	N	>1.0E5	N	2.0E2
	Magnetite, $FeO \cdot Fe_2O_3$	9.3E3	N	6.2E3	N	3.8E1	N
	Potassium Iron Silicate, $KFeSi_2O_6$	N	N	N	N	N	N
	Iron Carbonyls, $Fe(CO)_5$, $Fe(CO)_9$, $FE_3(CO)_{12}$	7.0E2	N	1.1E4	N	2.1E1	N
73	Ruthenium Ion, Ru^{+3}	N	N	N	N	N	N
74	Cobalt, Co	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobaltous, Co^{+2}	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobaltic, Co^{+3}	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobaltous Carbonate, hydrated, $CoCO_3 \cdot H_2O$ (as Co)	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobalt Carbide, Co_3C (as Co)	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobalt Sulfides, CoS, Co_2S_3 (as Co)	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobalt Arsenic Sulfide, CoAsS (as Co)	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobalt Arsenide, $CoAs_2$ (as Co)	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobalt Carbonyl, $Co(CO)_4$ (as Co)	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobaltous Oxide, CoO (as Co)	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
	Cobaltous Hydroxide, $Co(OH)_2$ (as Co)	5.0E1	N	7.5E2	2.5E2	1.5E0	5.0E-1
75	Rhodium Ion, Rh^{+3}	1.0E0	N	1.5E1	N	3.0E-2	N

Category	Compound	Air µg/m^3 (ppm)		Water µg/ℓ (ppm)		Solid Waste µg/g (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
76	Nickel, Ni	1.5E1	N	2.3E2	1.0E1	4.5E-1	2.0E-2
	Nickelous, Ni^{+2}	1.5E1	N	2.3E2	1.0E1	4.5E-1	2.0E-2
	Nickelic, Ni^{+3}	1.5E1	N	2.3E2	1.0E1	4.5E-1	2.0E-2
	Nickel Carbonyl, $Ni(CO)_4$	4.3E1	N	6.5E2	1.0E1 (as Ni)	1.0E0	2.0E-3 (as Ni)
	Nickelous Sulfide, NiS (as Ni)	1.5E1	N	2.3E2	1.0E1	4.5E-1	2.0E-2
	Nickel Arsenide, NiAs (as Ni)	1.5E1	N	2.3E2	1.0E1	4.5E-1	2.0E-2
	Nickel Oxide, NiO (as Ni)	1.5E1	N	2.3E2	1.0E1	4.5E-1	2.0E-2
	Nickel Antimonide, NiSb (as Ni)	1.5E1	N	2.3E2	1.0E1	4.5E-1	2.0E-2
	Nickel Arsenic Sulfide, NiAsS (as Ni)	1.5E1	N	2.3E2	1.0E1	4.5E-1	2.0E-2
77	Elemental Platinum, Pt	2.0E0	N	3.0E1	N	6.0E-2	N
78	Copper	2.0E2	N	5.0E3	5.0E1	1.0E1	1.0E-1
	Cuprous, Cu^{+}	2.0E2	N	5.0E3	5.0E1	1.0E1	1.0E-1
	Cupric, Cu^{+2}	2.0E2	N	5.0E3	5.0E1	1.0E1	1.0E-1
	Copper Fluoride, CuF_2 (as Cu)	2.0E2	N	5.0E3	5.0E1	1.0E1	1.0E-1
	Copper Oxides, CuO, Cu_2O (as Cu)	2.0E2	N	5.0E3	5.0E1	1.0E1	1.0E-1
	Copper Sulfate, $CuSO_4$ (as Cu)	2.0E2	N	5.0E3	5.0E1	1.0E1	1.0E-1
	Copper Sulfides, CuS, Cu_2S (as Cu)	2.0E2	N	5.0E3	5.0E1	11.0E1	1.0E-1
	Copper Carbonate, $CuCO_3$ (as Cu)	2.0E2	N	5.0E3	5.0E1	1.0E1	1.0E-1

Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
78 (cont'd)	Chalcopyrite Mineral, $CuFeS_2$	N	N	N	N	N	N
	Malachite Mineral, $CuCO_3 \cdot Cu(OH)_2$ (as Cu)	2.0E2	N	5.0E3	5.0E1	1.0E1	1.0E-1
79	Silver, Ag	1.0E1	N	2.5E2	5.0E0	5.0E-1	1.0E-1
	Silver Ion, Ag^+ (as Ag)	1.0E1	N	2.5E2	5.0E0	5.0E-1	1.0E-1
	Silver Chloride, AgCl (as Ag)	1.0E1	N	2.5E2	5.0E0	5.0E-1	1.0E-1
	Silver Cyanide, AgCN (as Ag)	1.0E1	N	2.5E2	5.0E0	5.0E-1	1.0E-1
	Silver Sulfide, Ag_2S (as Ag)	1.0E1	N	2.5E2	5.0E0	5.0E-1	1.0E-1
80	Elemental Gold	N	N	N	N	N	N
81	Zinc, Zn	4.0E3	N	2.5E4	1.0E2	5.0E1	2.0E-1
	Elemental Zinc, Zn	4.0E3	N	2.5E4	1.0E2	5.0E1	2.0E-1
	Zinc Ion, Zn^{+2}	4.0E3	N	2.5E4	1.0E2	5.0E1	2.0E-1
	Zinc Oxide, ZnO (as Zn)	4.0E3	N	2.5E4	1.0E2	5.0E1	2.0E-1
	Zinc Sulfate, $ZnSO_4$ (as Zn)	4.0E3	N	2.5E4	1.0E2	5.0E1	2.0E-1
	Zinc Sulfide, ZnS (as Zn)	4.0E3	N	2.5E4	1.0E2	5.0E1	2.0E-1
82	Cadmium, Cd	1.0E1	N	5.0E1	1.0E0	1.0E-1	2.0E-3
	Elemental Cadmium, Cd	1.0E1	N	5.0E1	1.0E0	1.0E-1	2.0E-3
	Cadmium Ion, Cd^{+2}	1.0E1	N	5.0E1	1.0E0	1.0E-1	2.0E-3
	Cadmium Sulfide, CdS (as Cd)	1.0E1	N	5.0E1	1.0E0	1.0E-1	2.0E-3
	Cadmium Oxide, CdO (as Cd)	1.0E1	N	5.0E1	1.0E0	1.0E-1	2.0E-3
83	Mercury, Hg	5.0E1	1.0E1	1.0E1	2.5E2	2.0E-2	5.0E-1

Category	Compound	Air $\mu g/m^3$ (ppm)		Water $\mu g/\ell$ (ppm)		Solid Waste $\mu g/g$ (ppm)	
		Health	Ecology	Health	Ecology	Health	Ecology
83 (cont'd)	Elemental Mercury, Hg	5.0E1	1.0E1	1.0E1	2.5E2	2.0E2	5.0E-1
	Mercurous, Hg_2^{++}	5.0E1	1.0E1	1.0E1	2.5E2	2.0E-2	5.0E-1
	Mercuric, Hg^{++}	5.0E1	1.0E1	1.0E1	2.5E2	2.0E-2	5.0E-1
	Mercuric Sulfide, HgS	5.0E1	1.0E1	1.0E1	2.5E2	2.0E-2	5.0E-1
	Mercuric Chloride, $HgCl_2$	5.0E1	1.0E1	1.0E1	2.5E2	2.0E-2	5.0E-1
84	Lanthanum, La	1.1E5	N	1.7E6	N	3.4E3	N
	Cerium, Ce (Ce^{+3}, Ce^{+4}, Ce_2O_3)	3.7E4	N	5.5E5	N	1.1E3	N
	Praseodymium, Pr (Pr^{+3})	5.1E4	N	7.7E5	N	1.5E3	N
	Neodymium, Nd (Nd^{+3})	N	N	N	N	N	N
	Samarium, Sm (Sm^{+3})	5.3E4	N	7.9E5	N	1.6E3	N
	Dysprosium, Dy (Dy^{+3})	9.3E3	N	2.3E5	N	4.6E2	N
85	Uranium, U (U^{+6})	9.0E0	N	6.0E4	5.0E2	1.2E2	1.0E0
	Thorium, Th (Th^{+4})	4.2E2	N	6.3E3	N	1.3E0	N

APPENDIX D

Hazard Indicators for Substances Addressed by MEG Charts

INTRODUCTION

Hazard potential values indicative of human health hazards have been calculated on the basis of EPC's for contaminants in air for all those substances addressed by MEG charts in the report. Table D-1 lists substances by category with their respective hazard potential values and their "X," "XX," and "XXX" designations where appropriate. Table D-2 presents the same information with the list arranged in descending order of hazard.

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TABLE D-1. HAZARD POTENTIAL VALUES FOR COMPOUNDS PRESENTLY ADDRESSED BY MEG CHARTS

Category	Compound	Hazard Potential	Indicator
1A	Methane	4	
	Ethane	4	
	Propane	4	
	Butanes	4	
1B	Ethylene	4	
	Propylene	4	
1C	Acetylene	4	
2A	Methyl chloride	4	
	Methylene chloride	4	
2B	Vinyl chloride	10.5	
3	1, 4 Dioxane	4	
4	2,2'-Dichloroethyl ether	8	
5A	Methanol	5	
	Ethanol	5	
	1-Propanol	4	
	n-Butanol	4	
	Isobutyl alcohol	4	
	Pentanols (primary)	4	
5B	2-Propanol	4	
	2-Butanol	4	
	Pentanols (secondary)	4	
	1-Phenyl ethanol	12	
5C	Tert-butanol	4	
	Tertiary pentanol	8	
6A	Ethylene glycol	12	
6B	1-Chloro-2,3-epoxy propane	9	
7A	Formaldehyde	15.5	x
	Acetaldehyde	4	
	Acrolein	16	x
	Propionaldehyde	8	
	Butyraldehyde	4	
7B	Benzaldehyde	8	
	Isophorone	10	
8A	Formic acid	12	
	Acetic acid	8	
	Benzoic acid	4	
	Phthalic acid	12	
8B	Hydroxyacetic acid	8	
8C	Formamide	10	
8D	Phthalate esters	15	x
9	Acetonitrile	8	
	Acrylonitrile (1-Cyanoethane)	8	
	Benzonitrile	8	
	Tetramethylsuccinonitrile	12	

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TABLE D-1 (continued)

Category	Compound	Hazard Potential	Indicator
10A	Ethylamine	8	
	Ethanolamine	12	
	Butylamines	12	
	Cyclohexylamine	8	
10B	Ethyleneimene	19.5	xx
	Dimethylamine	8	
10C	Aniline	10	
	Aminotoluenes	17	x
	Dimethylaniline	8	
	4-Aminobiphenyl	13	x
	4,4'-Diaminodiphenyl (Benzidine)	11.5	
	1-Aminonaphthalene	17	x
	2-Aminonaphthalene	17	x
10D	N,N-Dimethylaniline	8	
11	Diazomethane	22	xx
	Monomethylhydrazine	18	x
	N,N-Dimethylhydrazine	15	x
	N-N'Dimethylhydrazine	23.5	xx
	1,2-Diphenylhydrazine	15	x
	p-Dimethylaminoazobenzene	12	
12	N-Nitroso-Dimethylamine	27.5	xxx
	N-Nitroso-Diethylamine	19.5	xx
13A	Methanethiol	12	
	Ethanethiol	12	
	n-Butanethiol	12	
14	Benzenesulfonic acid	8	
15	Benzene	13	x
	Toluene	4	
	Ethyl benzene	4	
	Indan	4	
	Indene	8	
	Biphenyl	12	
	Xylenes	4	
	Tetrahydronaphthalene	4	
16A	Chlorobenzene	4	
	1,2-Dichlorobenzene	4	
	1,4-Dichlorobenzene	5	
	2-Chlorotoluene	4	
	Polychlorinated biphenyls	20	xx
16B	α-Chlorotoluene	11.5	
17	Nitrobenzene	15	
	4-Nitrobiphenyl	13	x
	1-Chloro-2-Nitrobenzene	15	x
	Nitrotoluenes	8	
	Dinitrotoluenes	15	x
18A	Phenol	10	
	Cresols	10	
	Phenyl phenols	10.5	
	Xylenols	15	x
	Alkyl cresols	10	
18B	Catechol	10	
18C	Indanols	5	

TABLE D-1 (continued)

Category	Compound	Hazard Potential	Indicator
19	2-chlorophenol	10	
	2,4-dichlorophenol	13	x
20	2-Nitrophenol	10	
	3-Nitrophenol	15	x
	4-Nitrophenol	15	x
	Dinitrophenols	15	x
	4,6-Dinitro-o-cresol	20	xx
	2,4,6-Trinitrophenol	20	xx
21	Naphthalene	9	
	Anthracene	6	
	Phenanthrene	12	
	Naphthance	-	
	Benz(a)anthracene (1,2-Benzanthracene)	24	xx
	7,12-Dimethylbenz(a)anthracene	26	xxx
	Benzo(c)phenanthrene	6	
	Chrysene	12	
	Methylchrysenes	12	
	Triphenylene	-	
	Pyrene	6	
	Dimethyl pyrenes	-	
	Benzo(g)chrysene	6	
	Dibenz(a,c)anthracene	6	
	Dibenz(a,h)anthracene	28	xxx
	Benzo(a)pyrene	26	xxx
	Benzo(e)pyrene	12	
	Perylene	-	
	Picene (dibenzo(a,i)phenanthrene)	12	
	Dibenzo(a,h)pyrene	12	
	Dibenzo(a,i)pyrene	24	xx
	Dibenzo(a,ℓ)pyrene	12	
	Benzo(g,h,i)perylene	-	
	Coronene	-	
22	Fluorene	-	
	Fluoranthene	8	
	Benzo(j)fluoranthene	12	
	Benzo(b)fluoranthene	12	
	3-Methylcholanthrene	30	xxx
	Indeno(1,2,3-cd)pyrene	12	
23A	Pyridine	15	x
	Picolines	8	
	Collidines	8	
23B	Quinoline, isoquinoline	12	
	Methylquinolines, methylisoquinolines	8	
	Acridine	8	
	Benz(c)acridine	6	
	Dibenz(a,j)acridine	18	x
	Dibenz(a,h)acridine	18	
	Dibenz(c,h)acridine	6	
	2,3-Benz-4-azafluorene	-	

TABLE D-1 (continued)

Category	Compound	Hazard Potential	Indicator
23C	Pyrrole	12	
	Indole	8	
	Carbazole	8	
	Dibenzo(a,i)carbazole	6	
	Dibenzo(c,g)carbazole	18	x
	Dibenzo(a,g)carbazole	12	
24	Tetrahydrofuran	5	
25	Thiophene	12	
	Methyl thiophenes	12	
	Benzo(b)thiophene	8	
26A	Tetramethyl lead	20	xx
	Tetraethyl lead	18	x
	Alkyl mercury	20	xx
	Organotin	20	xx
26B	Ferrocene	8	
	Nickelocene	15.5	x
26C	Copper 8-hydroxyquinoline	14	x
27	Lithium	16	x
	Lithium hydride	16	x
29	Potassium	12	
32	Beryllium	30	xxx
33	Magnesium	12	
33B	Magnesium oxide	12	
35	Strontium	12	
36	Barium	16	x
37	Boron	12	
	Boron oxide	12	
38	Aluminum	12	
38B	Aluminum oxide	12	
39	Gallium	15	x
41	Thallium	20	xx
42C	Carbon monoxide	8	
	Carbon dioxide	4	
44	Germanium	16	x
46	Lead	22	xx
47A	Alkali cyanide	12	
47B	Hydrogen cyanide	15	x
	Ammonia	8	
	Hydrazine	19.5	xx
48	Phosphorus	20	xx
48A	Phosphate	-	
48B	Phosphine	20	xx
49	Arsenic	25	xxx
49C	Arsine	25	xxx
	Arsenic trioxide	25	xxx
50	Antimony	20	xx
50C	Antimony trioxide	26	xxx
51	Bismuth	20	xx
52	Ozone	8	xx

TABLE D-1 (continued)

Category	Compound	Hazard Potential	Indicator
53C	Carbonyl sulfide	4	
53D	Hydrogen sulfide	12	
	Carbon disulfide	8	
54	Selenium	26	xxx
54C	Hydrogen selenide	20	xx
55	Tellurium	16	x
60	Scandium	8	
62	Titanium	12	
65	Vanadium	16	x
68	Chromium	30	xxx
69	Molybdenum	12	
70	Tungsten	12	
71	Manganese	15	x
74	Cobalt	24	xx
76	Nickel	26	xxx
76B	Nickel carbonyl	24	xx
78	Copper	20	xx
79	Silver	14	x
81	Zinc	12	
82	Cadmium	30	xxx
83	Mercury	30	xxx
85	Uranium	20	xx

TABLE D-2. HAZARD RANKING OF COMPOUNDS PRESENTLY ADDRESSED BY MEG CHARTS

Category	Compound	Hazard Potential	Indicator
22	3-Methylcholanthrene	30	xxx
32	Beryllium	30	xxx
68	Chromium	30	xxx
82	Cadmium	30	xxx
83	Mercury	30	xxx
21	Dibenz(a,h)anthracene	28	xxx
12	N-Nitrosodimethylamine	27.5	xxx
76	Nickel	26	xxx
21	7,12-Dimethylbenz(a)anthracene	26	xxx
21	Benzo(a)pyrene	26	xxx
50C	Antimony trioxide	26	xxx
54	Selenium	26	xxx
49	Arsenic	25	xxx
49C	Arsine	25	xxx
49C	Arsenic trioxide	25	xxx
21	Benz(a)anthracene	24	xx
21	Dibenzo(a,i)pyrene	24	xx
74	Cobalt	24	xx
76B	Nickel carbonyl	24	xx
11	N,N'-Dimethylhydrazine	23.5	xx
11	Diazomethane	22	xx
46	Lead	22	xx
16A	Polychlorinated biphenyls	20	xx
20	4,6-Dinitro-o-cresol	20	xx
20	2,4,6-Trinitrophenol	20	xx
26A	Tetramethyllead	20	xx
26A	Alkyl mercury	20	xx
26A	Organotin	20	xx
41	Thallium	20	xx
48	Phosphorus	20	xx
48B	Phosphine	20	xx
50	Antimony	20	xx
51	Bismuth	20	xx
54C	Hydrogen selenide	20	xx
78	Copper	20	xx
85	Uranium	20	xx
10B	Ethyleneimine	19.5	xx
12	N-Nitrosodiethylamine	19.5	xx
47B	Hydrazine	19.5	xx
11	Monomethylhydrazine	18	x
23B	Dibenz(a,j)acridine	18	x
23B	Dibenz(a,h)acridine	18	x
23C	Dibenzo(c,g)carbazole	18	x
26A	Tetraethyllead	18	x
10C	Aminotoluenes	17	x
10C	1-Aminonaphthalene	17	x
10C	2-Aminonaphthalene	17	x

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TABLE D-2 (continued)

Category	Compound	Hazard Potential	Indicator
7A	Acrolein	16	x
27	Lithium	16	x
27	Lithium hydride	16	x
36	Barium	16	x
44	Germanium	16	x
55	Tellurium	16	x
65	Vanadium	16	x
7A	Formaldehyde	15.5	x
26B	Nickelocene	15.5	x
8D	Phthalate esters	15	x
11	N,N-Dimethylhydrazine	15	x
11	1,2-Diphenylhydrazine	15	x
17	Nitrobenzene	15	x
17	1-Chloro-2-nitrobenzene	15	x
17	Dinitrotoluenes	15	x
18A	Xylenols	15	x
20	3-Nitrophenol	15	x
20	4-Nitrophenol	15	x
20	Dinitrophenols	15	x
23A	Pyridine	15	x
39	Gallium	15	x
47B	Hydrogen cyanide	15	x
71	Manganese	15	x
26C	Copper-8-hydroxyquinoline	14	x
79	Silver	14	x
10C	4-Aminobiphenyl	13	x
15	Benzene	13	x
17	4-Nitrobiphenyl	13	x
19	2,4-Dichlorophenol	13	x
5B	1-Phenyl ethanol	12	
6A	Ethylene glycol	12	
8A	Formic acid	12	
8A	Phthalic acid	12	
9	Tetramethylsuccinonitrile	12	
10A	Ethanolamine	12	
10A	Butylamines	12	
11	p-Dimethylaminoazobenzene	12	
13A	Methanethiol	12	
13A	Ethanethiol	12	
13A	n-Butanethiol	12	
15	Biphenyl	12	
21	Phenanthrene	12	
21	Chrysene	12	
21	Methylchrysenes	12	
21	Benzo(e)pyrene	12	
21	Picene	12	
21	Dibenzo(a,h)pyrene	12	
21	Dibenzo(a,l)pyrene	12	
22	Benzo(j)fluoranthene	12	
22	Benzo(b)fluoranthene	12	
22	Indeno(1,2,3-cd)pyrene	12	

TABLE D-2 (continued)

Category	Compound	Hazard Potential	Indicator
23B	Quinoline, isoquinoline	12	
23C	Pyrrole	12	
23C	Dibenzo(a,g)carbazole	12	
25	Thiophene	12	
25	Methyl thiophenes	12	
29	Potassium	12	
33	Magnesium	12	
33B	Magnesium oxide	12	
35	Strontium	12	
37	Boron	12	
37	Boron oxide	12	
38	Aluminum	12	
38B	Aluminum oxide	12	
47A	Alkali cyanide	12	
53D	Hydrogen sulfide	12	
62	Titanium	12	
69	Molybdenum	12	
70	Tungsten	12	
81	Zinc	12	
10C	Benzidine	11.5	
16B	α-Chlorotoluene	11.5	
2B	Vinyl chloride	10.5	
18A	Phenyl phenols	10.5	
7B	Isophorone	10	
8C	Formamide	10	
10C	Aniline	10	
18A	Phenol	10	
18A	Cresols	10	
18A	Alkyl cresols	10	
18B	Catechol	10	
19	2-Chlorophenol	10	
20	2-Nitrophenol	10	
6B	1-Chloro-2,3-epoxy propane	9	
21	Naphthalene	9	
4	2,2'-Dichloroethyl ether	8	
5C	Tertiary pentanol	8	
7A	Propionaldehyde	8	
7B	Benzaldehyde	8	
8A	Acetic acid	8	
8B	Hydroxyacetic acid	8	
9	Acetonitrile	8	
9	Acrylonitrile	8	
9	Benzonitrile	8	
10A	Ethylamine	8	
10A	Cyclohexylamine	8	
10B	Dimethylamine	8	
10C	Dimethylaniline	8	
10D	N,N-Dimethylaniline	8	
14	Benzenesulfonic acid	8	
15	Indene	8	
17	Nitrotoluenes	8	

TABLE D-2 (continued)

Category	Compound	Hazard Potential	Indicator
22	Fluoranthene	8	
23A	Picolines	8	
23A	Collidines	8	
23B	Methylquinolines, methylisoquinolines	8	
23B	Acridine	8	
23C	Indole	8	
23C	Carbazole	8	
25	Benzo(b)thiophene	8	
26B	Ferrocene	8	
42C	Carbon monoxide	8	
47B	Ammonia	8	
52	Ozone	8	
53D	Carbon disulfide	8	
60	Scandium	8	
21	Anthracene	6	
21	Benzo(c)phenanthrene	6	
21	Pyrene	6	
21	Benzo(g)chrysene	6	
21	Dibenz(a,c)anthracene	6	
23B	Benz(c)acridine	6	
23B	Dibenz(c,h)acridine	6	
23C	Dibenzo(a,i)carbazole	6	
5A	Methanol	5	
5A	Ethanol	5	
16A	1,4-Dichlorobenzene	5	
18C	Indanols	5	
24	Tetrahydrofuran	5	
1A	Methane	4	
1A	Ethane	4	
1A	Propane	4	
1A	Butanes	4	
1B	Ethylene	4	
1B	Propylene	4	
1C	Acetylene	4	
2A	Methyl chloride	4	
2A	Methylene chloride	4	
3	1,4-Dioxane	4	
5A	1-Propanol	4	
5A	n-Butanols	4	
5A	Isobutyl alcohol	4	
5A	Pentanols (primary)	4	
5B	2-Propanol	4	
5B	2-Butanol	4	
5B	Pentanols (secondary)	4	
5C	Tert-butanol	4	
7A	Acetaldehyde	4	
7A	Butyraldehyde	4	
8A	Benzoic acid	4	
15	Toluene	4	
15	Ethyl benzene	4	
15	Indan	4	

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TABLE D-2 (continued)

Category	Compound	Hazard Potential	Indicator
15	Xylenes	4	
15	Tetrahydronaphthalene	4	
16A	Chlorobenzene	4	
16A	1,2-Dichlorobenzene	4	
16A	2-Chlorotoluene	4	
42C	Carbon dioxide	4	
53C	Carbonyl sulfide	4	

The following compounds have not been assigned hazard potential values:

Category	Compound
21	Naphthacene
21	Triphenylene
21	Dimethyl pyrenes
21	Perylene
21	Benzo(g,h,i)perylene
21	Coronene
22	Fluorene
23B	2,3-Benz-4-azafluorene
48A	Phosphate

APPENDIX E

MEG Charts and Background Information Summaries for 216 Chemical Substances

Appendix E of the MEG's report is contained in Volume II.

APPENDIX F

Alphabetical Cross-Reference of Preferred Names and Synonyms for Appendix E

INTRODUCTION

This alphabetical listing of synonyms and preferred names of compounds addressed by MEG charts is provided to aid those persons unfamiliar with the category system used in the report, and to allow access to a given compound through any of its recognized synonyms. Category numbers as well as page numbers for the background information summaries are provided.

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INDEX OF SYNONYMS FOR CHEMICAL SUBSTANCES

Compound/Element	Category	Page
Acetaldehyde	7A	E-58
Acetic acid	8A	E-72
Acetic aldehyde (see Acetaldehyde)	7A	E-58
Acetonitrile	9	E-84
Acetylene	1C	E-16
Acridine	23B	E-282
Acrolein	7A	E-60
Acrylic aldehyde (see Acrolein)	7A	E-60
Acrylon (see Acrylonitrile)	9	E-86
Acrylonitrile	9	E-86
Alkali cyanides	47	E-370
Alkyl cresols	18A	E-190
Alkyl mercury compounds	26A	E-318
Aluminum and Aluminum compounds (as Aluminum)	38	E-348
Alumina (see Aluminum Oxide)	38	E-350
Aluminum Oxide	38	E-350
Alundum (see Aluminum Oxide)	38	E-350
Aminobenzene (see Aniline)	10C	E-104
4-Aminobiphenyl	10C	E-110
1-Aminobutane (see Butylamines)	10A	E-96
2-Aminobutane (see Butylamines)	10A	E-96
Aminobutanes (see Butylamines)	10A	E-96
Aminocyclohexane (see Cyclohexylamine)	10A	E-98
Aminodimethylbenzenes (see Dimethylaniline)	10C	E-108
1-Aminoethane (see Ethylamine)	10A	E-92
2-Aminoethanol (see Ethanolamine)	10A	E-94
2-Amino-2-methylpropane (see Butylamines)	10A	E-96
1-Aminonaphthalene	10C	E-114
2-Aminonaphthalene	10C	E-116

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Compound/Element	Category	Page
Aminotoluenes	10C	E-106
Ammonia	47	E-364
Ammonia gas (see Ammonia)	47	E-364
Amyl alcohols (see Pentanols)	5A, 5B	E-38, E-44
t-Amyl alcohol (see t-Pentanol)	5C	E-50
Aniline	10C	E-104
Anthracene	21	E-214
Antimony and Antimony compounds (as Antimony)	50	E-384
Antimonous oxide (see Antimony trioxide)	50	E-386
Antimony black (see Antimony and Antimony compounds)	50	E-384
Antimony trioxide	50	E-386
Argentum (see Silver)	79	E-426
Aroclors (see PCB's)	16A	E-168
Arsenic and Arsenic compounds (as Arsenic)	49	E-378
Arsenic hydride (see Arsine)	49	E-380
Arsenic (111) oxide (see Arsenic trioxide)	49	E-382
Arsenic sesquioxide (see Arsenic trioxide)	49	E-382
Arsenic trioxide	49	E-382
Arseniuretted hydrogen (see Arsine)	49	E-380
Arsenous anhydride (see Arsenic trioxide)	49	E-382
Arsenous hydride (see Arsine)	49	E-380
Arsenous oxide (see Arsenic trioxide)	49	E-382
Arsenous oxide anhydride (see Arsenic trioxide)	49	E-382
Arsine	49	E-380
10-Azaanthracene (see Acridine)	23B	E-282
Azabenzene (see Pyridine)	23A	E-272
1-Aza-2,4-cyclopentadiene (see Pyrrole)	23C	E-294
Azacyclopropane (see Ethyleneimine)	10B	E-100
9-Azafluorene (see Carbazole)	23C	E-298
1-Azaindene (see Indole)	23C	E-296
Azine (see Pyridine)	23A	E-272

Compound/Element	Category	Page
Azole (see Pyrrole)	23C	E-294
Azimethylene (see Diazomethane)	11	E-120
BAP (see Benzo(a)pyrene)	21	E-242
Barium and Barium compounds (as Barium)	36	E-342
Benz(j)aceanthrylene-1,2-dihydro-3-methyl (see 3-Methylcholanthrene)	22	E-268
Benz(e)acephenanthrylene (see Benzo(b)fluoranthene)	22	E-266
Benz(c)acridine	23B	E-284
Benzaldehyde	7A	E-66
Benz(a)anthracene	21	E-220
1,2-Benzanthracene (see Benz(a)anthracene)	21	E-220
2,3-Benzanthracene (see Naphthacene)	21	E-218
2,3-Benz-4-azafluorene	23B	E-292
1-Benzazine (see Quinoline, Isoquinoline)	23B	E-278
1-Benzazole (see Indole)	23C	E-296
o-Benzenediol (see Catechol)	18B	E-192
Benzene	15	E-144
Benzenecarbinal (see Benzaldehyde)	7A	E-60
Benzenecarboxylic acid (see Benzoic acid)	8A	E-74
1,2-Benzenedicarboxylic acid (see Phthalic acid)	8A	E-76
Benzenesulfonic acid	14A	E-142
Benzidine	10C	E-112
2,3-Benzindene (see Fluorene)	22	E-260
Benz(a)phenanthrene (see Chrysene)	21	E-226
Benzo(g)chrysene	21	E-236
Benzo(b)fluoranthene	22	E-266
Benzo(j)fluoranthene	22	E-264
2,3-Benzofluoranthene (see Benzo(b)fluoranthene)	22	E-266
10,11-Benzofluoranthene (see Benzo(j)flouranthene)	22	E-264
Benzo(j,k)fluorene (see Fluoranthene)	22	E-262
Benzoic acid	8A	E74
Benzoic aldehyde (see Benzaldehyde)	7A	E-66

Compound/Element	Category	Page
Benzol (see Benzene)	15	E-144
Benzonitrile	9	E-88
Benzo(rst)pentaphene (see Dibenzo(a,i)pyrene)	21	E-252
1,12-Benzoperylene (see Benzo(ghi)perylene)	21	E-256
Benzo(ghi)perylene	21	E-256
Benzo(b)phenanthrene (see Benz(a)anthracene)	21	E-220
Benzo(c)phenanthrene	21	E-224
Benzo(def)phenanthrene (see Pyrene)	21	E-232
1,2-Benzophenanthrene (see Chrysene)	21	E-226
2,3-Benzophenanthracene (see Benz(a)anthracene)	21	E-220
3,4-Benzophenanthrene (see Benzo(c)phenanthrene)	21	E-224
1,2-Benzpyrene (see Benzo(a)pyrene)	21	E-242
Benzo(a)pyrene	21	E-242
Benzo(e)pyrene	21	E-244
4,5-Benzopyrene (see Benzo(e)pyrene)	21	E-244
Benzo(b)pyridine (see Quinoline, Isoquinoline)	23B	E-278
Benzo(c)pyridine (see Quinoline, Isoquinoline)	23B	E-278
2,3-Benzopyrrole (see Indole)	23C	E-296
Benzo(b)quinoline (see Acridine)	23B	E-282
Benzothiofuran (see Benzo(b)thiophene)	25	E-312
2,3-Benzothiophene (see Benzo(b)thiophene)	25	E-312
Benzo(b)thiophene	25	E-312
Benzo(b)triphenylene (see Dibenz(a,c)anthracene)	21	E-238
Benzyl chloride (see α-Chlorotoluene)	16B	E-170
Beryllium and Beryllium compounds (as Beryllium)	32B	E-334
Bibenzene (see Biphenyl)	15	E-154
Bimethyl (see Ethane)	1A	E-6
Biphenyl	15	E-154
4-Biphenylamine (see 4-Aminobiphenyl)	10C	E-110
Biphenylol (see Phenylphenol)	18A	E-186
Bismuth and Bismuth compounds (as Bismuth)	51	E-388

Compound/Element	Category	Page
Boric acid, fused (see Boron oxide)	37	E-346
Boric acid, glass (see Boron oxide)	37	E-346
Boric Anhydride (see Boron oxide)	37	E-346
Boron and Boron compounds (as Boron)	37	E-344
Boron oxide	37	E-346
Boron sesquioxide (see Boron oxide)	37	E-346
Boron trioxide (see Boron oxide)	37	E-346
Butanal (see Butyraldehyde)	7A	E-64
Butanes	1A	E-10
n-Butane (see Butanes)	1A	E-10
1-Butanethiol (see n-Butanethiol)	13A	E-140
n-Butanethiol	13A	E-140
n-Butanol	5A	E-34
2-Butanol	5B	E-42
t-Butanol	5C	E-48
Butric aldehyde (see Butyraldehyde)	7A	E-64
Butyl alcohol (see n-Butanol)	5A	E-34
s-Butyl alcohol (see 2-Butanol)	5B	E-42
t-Butyl alcohol (see t-Butanol)	5C	E-48
sec-Butyl alcohol (see 2-Butanol)	5B	E-42
n-Butyl aldehyde (see Butyraldehyde)	7A	E-64
Butylamines	10A	E-96
t-Butylamines (see Butylamines)	10A	E-96
n-Butyl mercaptan (see n-Butanethiol)	13A	E-140
n-Butylthioalcohol (see n-Butanethiol)	13A	E-140
Butyraldehyde	7A	E-64
Cadmium and Cadmium compounds (as Cadmium)	82	E-430
Carbazole	23C	E-298
Carbinol (see Methanol)	5A	E-28
Carbolic acid (see Phenol)	18A	E-182
Carbon bisulfide (see Carbon disulfide)	53	E-396
Carbon dioxide	42	E-358

Compound/Element	Category	Page
Carbon disulfide	53	E-396
Carbon monoxide	42	E-356
Carbonic acid gas (see Carbon dioxide)	42	E-358
Carbonic anhydride (see Carbon dioxide)	42	E-358
Carbon oxysulfide (see Carbonyl sulfide)	53	E-392
Carbonyl sulfide	53	E-392
Catechol	18B	E-192
Chinoline (see Quinoline, Isoquinoline)	23B	E-278
Chlorobenzene	16A	E-160
1-Chloro-2,3-epoxypropane	6B	E-54
Chloroethene (see Vinyl chloride)	2B	E-22
Chloroethylene (see Vinyl chloride)	2B	E-22
bis-2-Chloroethyl ether (see 2,2'-Dichlorodiethylether)	4	E-26
Chloromethane (see Methyl chloride)	2A	E-18
1-Chloro-2-nitrobenzene	17	E-176
o-Chloronitrobenzene (see 1-chloro-2-nitrobenzene	17	E-176
2-Chlorophenol	19	E-196
o-Chlorophenol (see 2-Chlorophenol)	19	E-196
α-Chlorotoluene	16B	E-170
2-Chlorotoluene	16A	E-166
o-Chlorotoluene (see 2-Chlorotoluene)	16A	E-166
Chromium and Chromium compounds (as Chromium)	68	E-410
Chrysene	21	E-226
α-Chrysidine (see Benz(c)acridine)	23B	E-284
Chrysogen (see Naphthacene)	21	E-218
Cobalt and Cobalt compounds (as Cobalt)	74	E-418
Collidines	23A	E-276
Colloidal manganese (see Manganese and Manganese compounds)	71	E-416
Complexed copper (see Copper-8-hydroxyquinoline)	26C	E-326
Copper and Copper compounds (as Copper)	78	E-424

Compound/Element	Category	Page
Copper-8-hydroxyquinoline	26C	E-326
Coronene	21	E-258
Corundum (see Aluminum oxide)	38	E-350
Cresols	18A	E-184
Cresylic acid (see Cresols)	18A	E-184
Cuprum (see Copper)	78	E-424
Cyanides (see Alkali cyanides, Hydrogen cyanide)	47	E-370, E-368
Cyanobenzene (see Benzonitrile)	9	E-88
Cyanoethylene (see Acrylonitrile)	9	E-86
Cyclohexylamine	10A	E-98
Cyclotetramethylene oxide (see Tetrahydrofuran)	24	E-306
Diamide (see Hydrazine)	47	E-366
4,4'-Diaminodiphenyl (see Benzidine)	10C	E-112
Diazirine (see Diazomethane)	11	E-120
Diazomethane	11	E-120
1,2-5,6-Dibenzacridine (see Dibenz(a,h)acridine)	23B	E-288
1,2-7,8-Dibenzacridine (see Dibenz(a,j)acridine)	23B	E-286
3,4-5,6-Dibenzacridine (see Dibenz(c,h)acridine)	23B	E-290
Dibenz(a,h)acridine	23B	E-288
Dibenz(a,j)acridine	23B	E-286
Dibenz(c,h)acridine	23B	E-290
1,2-3,4-Dibenzanthracene (see Dibenz(a,c)anthracene)	21	E-238
1,2-5,6-Dibenzanthracene (see Dibenz(a,h)anthracene)	21	E-240
Dibenz(a,c)anthracene	21	E-238
Dibenz(a,h)anthracene	21	E-240
Dibenz(de,kl)anthracene (see Perylene)	21	E-246
1,2-3,4-Dibenznaphthalene (see Triphenylene)	21	E-230
1,2-5,6-Dibenzocarbazole (see Dibenzo(a,g)carbazole)	23C	E-304
1,2-7,8-Dibenzocarbazole (see Dibenzo(a,i)carbazole)	23C	E-300
3,4-5,6-Dibenzocarbazole (see Dibenzo(c,g)carbazole)	23C	E-302
Dibenzo(a,i)carbazole	23C	E-300

Compound/Element	Category	Page
Dibenzo(c,g)carbazole	23C	E-302
Dibenzo(a,g)carbazole	23C	E-304
7H-Dibenzo(a,g)carbazole (see Dibenzo(a,g)carbazole)	23C	E-304
7H-Dibenzo(a,i)carbazole (see Dibenzo(a,i)carbazole)	23C	E-300
7H-Dibenzo(c,g)carbazole (see Dibenzo(c,g)carbazole)	23C	E-302
Dibenzo(b,def)chrysene (see Dibenzo(a,h)pyrene)	21	E-250
Dibenzo(def,p)chrysene (see Dibenzo(a,l)pyrene)	21	E-254
1,2-3,4-Dibenzophenanthrene (see Benzo(g)chrysene)	21	E-236
Dibenzo(a,i)phenanthrene (see Picene)	21	E-248
1,2-9,10-Dibenzopyrene (see Dibenzo(a,l)pyrene)	21	E-254
Dibenzo(a,h)pyrene	21	E-250
Dibenzo(a,i)pyrene	21	E-252
Dibenzo(a.i)pyrene	21	E-254
Dibenzo(b,e)pyridine (see Acridine)	23B	E-282
Dibenzo(b,d)pyrrole (see Carbazole)	23C	E-298
1,2-7,8-Dibenzphenanthrene (see Picene)	21	E-248
Di-n-butyl phthalate (see Phthalate esters)	8D	E-82
1,2-Dichlorobenzene	16A	E-162
1,4-Dichlorobenzene	16A	E-164
o-Dichlorobenzene (see 1,2-Dichlorobenzene)	16A	E-162
p-Dichlorobenzene (see 1,4-Dichlorobenzene)	16A	E-164
2,2'Dichlorodiethyl ether	4	E-26
Dichloromethane (see Methylene chloride)	2A	E-20
2,4-Dichlorophenol	19	E-198
Dicyclopentadienyliron (see Ferrocene)	26B	E-322
Dicyclopentadienylnickel (see Nickelocene)	26B	E-324
1,4-Diethylene dioxide (see 1,4-Dioxane)	3	E-24
Diethylnitrosamine (see N-Nitrosodiethylamine)	12	E-134
Diethyl phthalate (see Phthalate esters)	8D	E-82
1,2-Dihydroxybenzene (see Catechol)	18B	E-192
o-Dihydroxybenzene (see Catechol)	18B	E-192

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Compound/Element	Category	Page
1,2-Dihydroxyethane (see Ethylene glycol)	6A	E-52
Dimazine (see N,N-Dimethylhydrazine)	11	E-124
Dimethyl (see Ethane)	1A	E-6
Dimethylamine	10B	E-102
p-Dimethylaminoazobenzene	11	E-130
4-Dimethylaminoazobenzene (see p-dimethylaminoazobenzene)	11	E-130
Dimethylaniline	10C	E-108
N,N-Dimethylaniline	10D	E-118
7,12-Dimethylbenz(a)anthracene	21	E-222
9,10-Dimethyl-1,2-benzanthracene (see 7,12-Dimethylbenz(a)anthracene)	21	E-222
Dimethylbenzene (see Xylenes)	15	E-156
Dimethylhydrazine (see N,N'-Dimethylhydrazine)	11	E-126
1,1-Dimethylhydrazine (see N,N-Dimethylhydrazine)	11	E-124
1,2-Dimethylhydrazine (see N,N'-Dimethylhydrazine)	11	E-126
N,N-Dimethylhydrazine	11	E-124
N,N'-Dimethylhydrazine	11	E-126
Dimethylhydroxybenzenes (see Xylenols)	18A	E-188
Dimethylmercury (see Alkyl mercury compounds)	26A	E-318
Dimethylmethane (see Propane)	1A	E-8
Dimethylnitrosamine (see N-Nitrosodimethylamine)	12	E-132
Dimethylphenylamine (see N,N-Dimethylaniline)	10C	E-108
Dimethylphenols (see Xylenols)	18A	E-188
Dimethyl phthalate (see Phthalate esters)	8D	E-82
Dimethyl pyrenes	21	E-234
3,4-Dimethyl pyrene (see Dimethyl pyrenes)	21	E-234
4,5-Dimethyl pyrene (see Dimethyl pyrenes)	21	E-234
peri-Dinaphthalene (see Perylene)	21	E-246
2,4-Dinitro-o-cresol (see 4,6-Dinitro-o-cresol)	20	E-208
4,6-Dinitro-o-cresol	20	E-208

Compound/Element	Category	Page
Dinitrohydroxybenzenes (see Dinitrophenols)	20	E-206
Dinitrophenols	20	E-206
Dinitrotoluenes	17	E-180
1,4-Dioxane	3	E-24
Diphenyl (see Biphenyl)	15	E-154
4,4'-Diphenylenediamine (see Benzidine)	10C	E-112
Diphenyleneimine (see Carbazole)	23C	E-298
Diphenylenemethane (see Fluorene)	22	E-260
1,2-Diphenylhydrazine	11	E-128
Divinyleneimine (see Pyrrole)	23C	E-294
Dry ice (see Carbon dioxide)	42	E-358
Epichlorhydrin (see 1-chloro-2,3-epoxypropane)	6B	E-54
1,4-Epoxybutane (see Tetrahydrofuran)	24	E-306
Ethanamine (see Ethylamine)	10A	E-92
Ethanal (see Acetaldehyde)	7A	E-58
Ethane	1A	E-6
1,2-Ethanediol (see Ethylene glycol)	6A	E-52
Ethanethiol	13A	E-138
Ethanoic acid (see Acetic acid)	8A	E-72
Ethanol	5A	E-30
Ethanolamine	10A	E-94
Ethene (see Ethylene)	1B	E-12
Ethine (see Acetylene)	1C	E-16
Ethyl alcohol (see Ethanol)	5A	E-30
Ethyl aldehyde (see Acetaldehyde)	7A	E-58
Ethylamine	10A	E-92
Ethyl benzene	15	E-148
Ethyl benzol (see Ethyl benzene)	15	E-148
Ethylene	1B	E-12
Ethylene glycol	6A	E-52

Compound/Element	Category	Page
Ethyleneimine	10B	E-100
Ethyl hydride (see Ethane)	1A	E-6
Ethyl mercaptan (see Ethanethiol)	13A	E-138
Ethyl methyl pyridines (see Collidines)	23A	E-276
Ethyl thioalcohol (see Ethanethiol)	13A	E-138
Ethyne (see Acetylene)	1C	E-16
Ferrocene	26B	E-322
Fluoranthene	22	E-262
Fluorene	22	E-260
Formaldehyde	7A	E-56
Formamide	8C	E-80
Formic acid	8A	E-70
Formic acid amide (see Formamide)	8C	E-80
Formylamine (see Formamide)	8C	E-80
Gallium and Gallium compounds (as Gallium)	39	E-352
Germanium and Germanium compounds (as Germanium)	44	E-360
Glycolic acid (see Hydroxyacetic acid)	8B	E-78
Glucinium (see Beryllium)	32	E-334
Grain Alcohol (see Ethanol)	5A	E-30
Hexabenzobenzene (see Coronene)	21	E-258
Hexahydroaniline (see Cyclohexylamine)	10A	E-98
Hydrazine	47	E-366
Hydrazobenzene (see 1,2-Diphenylhydrazine)	11	E-128
Hydrindene (see Indan)	15	E-150
Hydrogen arsenide (see Arsine)	49	E-380
Hydrogen cyanide	47A	E-368
Hydrogen phosphide (see Phosphine)	48	E-376
Hydrogen selenide	54	E-400
Hydrogen sulfide	53	E-394
Hydrosulfuric acid (see Hydrogen sulfide)	53	E-394

Compound/Element	Category	Page
Hydroxyacetic acid	8B	E-78
Hydroxybenzene (see Phenol)	18A	E-182
Hydroxybiphenyls (see Phenylphenol)	18A	E-186
Hydroxyethanoic acid (see Hydroxyacetic acid)	8B	E-78
2-Hydroxyethylamine (see Ethanolamine)	10A	E-94
Hydroxyhydrindene (see Indanols)	18C	E-194
Hydroxyindene (see Indanols)	18C	E-194
2-Hydroxyphenol (see Catechol)	18B	E-192
o-Hydroxyphenol (see Catechol)	18B	E-192
1-Hydroxypropane (see 1-Propanol)	5A	E-32
2-Hydroxypropane (see 2-Propanol)	5B	E-40
Hydroxytoluene (see Cresols)	18A	E-184
Indan	15	E-150
Indanols	18C	E-194
Indene	15	E-152
Indeno(1,2,3-cd)pyrene	22	E-270
11 H-Indeno(1,2-b)quinoline (see 2,3-Benz-4-azafluorene)	23B	E-292
Indole	23C	E-296
Indonaphthene (see Indene)	15	E-152
Isoacetophorone (see Isophorone)	7B	E-68
Isobutane (see Butane)	1A	E-10
Isobutyl alcohol	5A	E-36
Isophorone	7B	E-68
Isopropyl alcohol (see 2-Propanol)	5B	E-40
Isoquinoline (see Quinoline, Isoquinoline)	23B	E-278
Kalium (see Potassium and Potassium compounds)	29	E-332
Lead and Lead compounds (as Lead)	46	E-362
Leucoline (see Quinoline, Isoquinoline)	23B	E-278
Lithium and Lithium compounds (as Lithium)	27	E-328

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Compound/Element	Category	Page
Lithium hydride	27	E-330
Magnesium and Magnesium compounds (as Magnesium)	33	E-336
Magnesium oxide	33	E-338
Manganese and Manganese compounds (as Manganese)	71	E-416
Marsh gas (see Methane)	1A	E-4
Mercury and Mercury compounds (as Mercury) except alkyl	83	E-432
Methane	1A	E-4
Methanamide (see Formamide)	8C	E-80
Methanethiol	13A	E-136
Methane	1A	E-4
Methanoic acid (see Formic acid)	8A	E-70
Methanol	5A	E-28
Methyl alcohol (see Methanol)	5A	E-28
Methyl aldehyde (see Formaldehyde)	7A	E-56
Methylaniline (see Aminotoluenes)	10C	E-106
Methylbenzene (see Toluene)	15	E-146
Methyl-1,2-benzophenanthrene (see Methyl chrysenes)	21	E-228
α-Methylbenzyl alcohol (see 1-Phenylethanol)	5B	E-46
Methyl chloride	2A	E-18
1-Methyl-2-chlorobenzene (see 2-Chlorotoluene)	16A	E-166
3-Methylcholanthrene	22	E-268
20-Methylcholanthrene (see 3-Methylchloranthrene)	22	E-268
Methyl chrysenes	21	E-228
Methyl cyanide (see Acetonitrile)	9	E-84
2-Methyl-4,6-dinitrophenol (see 4,6-Dinotro-o-cresol)	20	E-208
Methylene bichloride (see Methylene chloride)	2A	E-20
Methylene chloride	2A	E-20
Methylene oxide (see Formaldehyde)	7A	E-56
Methyl ethylphenols (see Alkyl cresols)	18A	E-190
Methylethylpyridine (see Collidines)	23A	E-276
Methylhydrazine (see Monomethylhydrazine)	11	E-122
Methyl hydride (see Methane)	1A	E-4

Compound/Element	Category	Page
Methyl mercaptan (see Methanethiol)	13A	E-136
Methylmercury (see Alkyl mercury compounds)	26A	E-318
Methylmethane (see Ethane)	1A	E-6
Methylnitrobenzenes (see Nitrotoluenes)	17	E-178
Methylphenol (see Cresols)	18A	E-184
Methylphenylcarbinol (see 1-Phenylethanol)	5B	E-46
2-Methylpropane (see Butanes)	1A	E-10
2-Methyl-2-propanol (see t-Butanol)	5C	E-48
2-Methylpyridine (see Picolines)	23A	E-274
3-Methylpyridine (see Picolines)	23A	E-274
4-Methylpyridine (see Picolines)	23A	E-274
2- Methylquinoline	23B	E-280
Methylthiophenes	25	E-310
2-Methylthiophene (see Methylthiophenes)	25	E-310
3-Methylthiophene (see Methylthiophenes)	25	E-310
Molybdenum and Molybdenum compounds (as Molybdenum)	69	E-412
Monomethylhydrazine	11	E-122
Monomethylmercury (see Alkyl mercury compounds)	26A	E-318
Moth flakes (see Naphthalene)	21	E-212
Naphthacene	21	E-218
α-Naphthacridine (see Benz(c)acridine)	23B	E-284
Naphthalene	21	E-212
Naphthalin (see Naphthalene)	21	E-212
Naphthaline (see Naphthalene)	21	E-212
Naphthene (see Naphthalene)	21	E-212
1-Naphthylamine (see 1-Aminonaphthalene)	10C	E-114
α-Naphthylamine (see 2-Aminonaphthalene)	10C	E-116
β-Naphthylamine (see 2-Aminonaphthalene)	10C	E-116
Nickel and Nickel compounds (as Nickel)	76	E-420
Nickel carbonyl	76	E-422
Nickelocene	26B	E-324

Compound/Element	Category	Page
Nickel tetracarbonyl (see Nickel carbonyl)	76	E-442
Nitrobenzene	17	E-172
4-Nitrobiphenyl	17	E-174
p-Nitrobiphenyl (see 4-Nitrobiphenyl)	17	E-174
4-Nitrodiphenyl (see 4-Nitrobiphenyl)	17	E-174
2-Nitrophenol	20	E-200
3-Nitrophenol	20	E-202
4-Nitrophenol	20	E-204
m-Nitrophenol (see 3-Nitrophenol)	20	E-202
o-Nitrophenol (see 2-Nitrophenol)	20	E-200
p-Nitrophenol (see 4-Nitrophenol)	20	E-204
N-Nitrosodiethylamine	12	E-134
N-Nitrosodimethylamine	12	E-132
Nitrotoluenes	17	E-178
Organotin compounds	26A	E-320
Oxybenzene (see Phenol)	18A	E-182
Ozone	52	E-390
Pentanols (primary)	5A	E-38
Pentanols (secondary)	5B	E-44
t-Pentanol	5C	E-50
t-Pentyl alcohol (see t-Pentanol)	5C	E-50
Perylene	21	E-246
Phenanthrene	21	E-216
Phene (see Benzene)	15	E-144
Phenic acid (see Phenol)	18A	E-182
Phenol	18A	E-182
Phenylaldehyde (see Benzaldehyde)	7A	E-66
Phenylamine (see Aniline)	10C	E-104
p-Phenylaniline (see 4-Aminobiphenyl)	10C	E-110
Phenylbenzene (see Biphenyl)	15	E-154
Phenyl chloride (see Chlorobenzene)	16A	E-160

Compound/Element	Category	Page
Phenyl cyanide (see Benzonitrile)	9	E-88
2,3-O-Phenylenepyrene (see Indeno(1,2,3-cd)pyrene)	22	E-270
Phenylethane (see Ethylbenzene)	15	E-148
1-Phenylethanol	5B	E-46
Phenyl formic acid (see Benzoic acid)	8A	E-74
Phenylhydride (see Benzene)	15	E-144
Phenyl hydroxide (see Phenol)	18A	E-182
Phenylic acid (see Phenol)	18A	E-182
Phenylmethane (see Toluene)	15	E-146
Phenylphenols	18A	E-186
Phenylsulfonic acid (see Benzenesulfonic acid)	14A	E-142
Phosphate	48	E-374
Phosphine	48	E-376
Phosphorus	48	E-372
Phthalate esters	8D	E-82
Phthalic acid	8A	E-76
o-Phthalic acid (see Phthalic acid)	8A	E-76
Picene	21	E-248
Picolines	23A	E-274
Picric acid (see 2,4,6-Trinitrophenol)	20	E-210
Plumbum (see Lead)	46	E-362
Polychlorinated Biphenyls (PCB's)	16A	E-168
Potassium and Potassium compounds (as Potassium)	29	E-332
Potassium cyanide (see Alkali cyanides)	47	E-370
Propaldehyde (see Propionaldehyde)	7A	E-62
Propanal (see Propionaldehyde)	7A	E-62
Propane	1A	E-8
1-Propanol	5A	E-32
2-Propanol	5B	E-40
Propenal (see Acrolein)	7A	E-60
Propene (see Propylene)	1B	E-14

Compound/Element	Category	Page
Propionaldehyde	7A	E-62
n-Propyl alcohol (see 1-Propanol)	5A	E-32
Propylaldehyde (see Propionaldehyde)	7A	E-62
Propylene	1B	E-14
Pyrene	21	E-232
Pyridine	23A	E-272
Pyrocatechol (see Catechol)	18B	E-192
Pyrrole	23C	E-294
Quicksilver (see Mercury)	83	E-432
Quinaldine (see 2-Methylquinoline)	23B	E-280
Quinoline	23B	E-278
8-Quinolinol-copper II chelate (see Copper-8-hydroxyquinoline)	26C	E-326
Scandium	60	E-404
Selenium and Selenium compounds (as Selenium)	54	E-398
Selenium hydride (see Hydrogen selenide)	54	E-400
Silver and Silver compounds (as Silver)	79	E-426
Sodium cyanide (see Alkali cyanide)	47A	E-370
Stibium (see Antimony and Antimony compounds)	50	E-384
Strontium and Strontium compounds (as Strontium)	35	E-340
Sulfur hydride (see Hydrogen sulfide)	53	E-394
Tar camphor (see Naphthalene)	21	E-212
Tellurium and Tellurium compounds (as Tellurium)	55	E-402
Tetracene (see Naphthacene)	21	E-218
Tetraethyllead	26A	E-316
Tetraethylplumbane (see Tetraethyllead)	26A	E-316
Tetrahydrofuran	24	E-306
Tetrahydronaphthalene	15	E-158
Tetralin (see Tetrahydronaphthalene)	15	E-158
Tetraline (see Tetrahydronaphthalene)	15	E-158
Tetramethyllead	26A	E-314
Tetramethylplumbane (see Tetramethyllead)	26A	E-314

Compound/Element	Category	Page
Tetramethylsuccinonitrile	9	E-90
Thallium and Thallium compounds (as Thallium)	41	E-354
Thiofuran (see Thiophene)	25	E-308
Thionaphthene (see Benzo(b)thiophene)	25	E-312
Thiophene	25	E-308
Titanium and Titanium (as Titanium)	62	E-406
Toluene	15	E-146
Toluidines (see Aminotoluenes)	10C	E-106
Toluol (see Toluene)	15	E-146
o-Tolyl chloride (see 2-Chlorotoluene)	16A	E-166
Triatomic oxygen (see Ozone)	52	E-390
3,5,5-Trimethyl-2-cyclohexene-1 one (see Isophorone)	7B	E-68
Trimethylmethane (see Butanes)	1A	E-10
Trimethylpyridines (see Collidines)	23A	E-276
2,4,6-Trinitrophenol	20	E-210
Triphenylene	21	E-230
Tungsten and Tungsten compounds (as Tungsten)	70	E-414
Unsymmetrical dimethylhydrazine (see N,N Dimethylhydrazine)	11	E-124
Uranium and Uranium compounds (as Uranium)	85	E-434
Vanadium and Vanadium compounds (as Vanadium)	65	E-408
Vinyl chloride	2B	E-22
Vinyl cyanide (see Acrylonitrile)	9	E-86
White arsenic (see Arsenic trioxide)	49	E-382
White tar (see Naphthalene)	21	E-212
Wolfram (see Tungsten)	70	E-414
Wood alcohol (see Methanol)	5A	E-28
Xylenes	15	E-156
Xylenols	18A	E-188
Xylidines (see Dimethylaniline)	10C	E-108
Xylol (see Xylenes)	15	E-156
Zinc and Zinc compounds (as Zinc)	81	E-428

APPENDIX G.

Carcinogenesis

INTRODUCTION

In spite of the absence of a sound theory relating all known chemical carcinogens to their structures, there are some areas of agreement among researchers regarding mechanisms of cancer induction and the role of certain classes of chemicals in those mechanisms. It is the purpose of this appendix to present a brief overview of some of the most generally accepted theories and models that have been postulated to explain chemical carcinogenesis. Both organic compounds (with emphasis on polycyclic aromatic hydrocarbons) and metals are addressed. A basic discussion of DNA is included since the preponderance of carcinogenesis theories focuses on the alteration of DNA. A section on short-term bioassays (short-term tests which are used, or which might be used, in the attempt to detect chemical carcinogens) is also included. These tests are based largely on theories advanced in the earlier section on mechanisms.

It is hoped that the information provided in this appendix, although not directly related to the MEG's as developed in this report, may provide the basis for more refined models for deriving EPC's and MATE's for suspected carcinogens in the future.

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MECHANISMS FOR THE INDUCTION OF CANCER AND THEORIES RELATING CARCINOGENESIS TO PHYSICO-CHEMICAL PROPERTIES OF CHEMICAL CARCINOGENS

The appearance of cells whose growth does not obey the normal rules of reproduction and the invasion and proliferation of those cells in normal tissue, coupled with loss of specific function, are the conditions generally accepted as a definition of cancer. The transformations necessary for the appearance of cancerous cells have been linked to viral, radiative, and chemical agents.

Chemicals that induce formation of cancer are called chemical carcinogens. A chemical carcinogen can be defined as an agent that induces cancer at a site or target in the organism which would not occur if the chemical were not present.

Most of the chemical substances known to cause cancer are organic, and most of the research on chemical carcinogenesis is directed to the understanding of carcinogenesis caused by organic chemicals. This is understandable considering that the first chemicals suspected of causing cancers were the polycyclic aromatic hydrocarbons. It is known that carcinogenic organic compounds are found in such diverse classes as polycyclic aromatic hydrocarbons, nitrosoamines, aromatic amines, halogenated hydrocarbons, acridines, isothiocyanates, and aflatoxins.

A small number of metals and their salts, as well as some complex silicates (asbestos), are also known to be carcinogenic. Certain metallo-organic compounds (where there is a covalent bond between the metal and the organic moiety) and certain chelates (where the metallic ion is coordinated to atoms with free electron pairs to form a five- or six-membered ring) have also shown carcinogenic activity.

There are no obvious structural similarities among all the chemicals known to induce cancer although may researchers have investigated theories advancing a variety of possible common denominators. Most chemical carcinogens could be more correctly described as procarcinogens--i.e., chemicals that require activation (usually enzymatic) before they can elicit a carcinogenic response in an organism. This concept of procarcinogens may explain the lack of success in the search for a common structural element among chemical carcinogens since the biologically active form may differ from that of its precursor. The ultimate carcinogen in most cases is believed to be electrophilic in nature.

The main thrust of research in the field of chemical carcinogens is currently directed to the understanding of what happens at the cellular level to induce tumor formation: What transforms a procarcinogen into an active form? Which cellular component will it attack? How will that attack increase the susceptibility of the tissue for transformation into a malignant growth?

CARCINOGENESIS AND DNA

There is general agreement among researchers that a chemical interaction between a carcinogen and cellular material is a requisite for carcinogenesis and that merely physical interactions do not induce cancer. (It is known that carcinogens can interact with various constituents of cellular material such as nucleic acid and proteins). The interaction regarded as critical by most researchers is the one involving the ultimate carcinogen and DNA. It is likely that it involves an attack of the nucleophilic centers in DNA.

DNA orders all chemical activity within a cell, and it may be assumed that any change in the DNA must result in a change in the cell's activity. Conversely, when changes within a cell become evident, an obvious possible cause might be assumed to result from a malfunction in the DNA. The study of chemical carcinogenesis, then, has centered on the mechanisms by which chemical substances might bring about malfunction in DNA. Before continuing the discussion of carcinogenesis, it is imperative that the structure and function of DNA within the cell be understood.

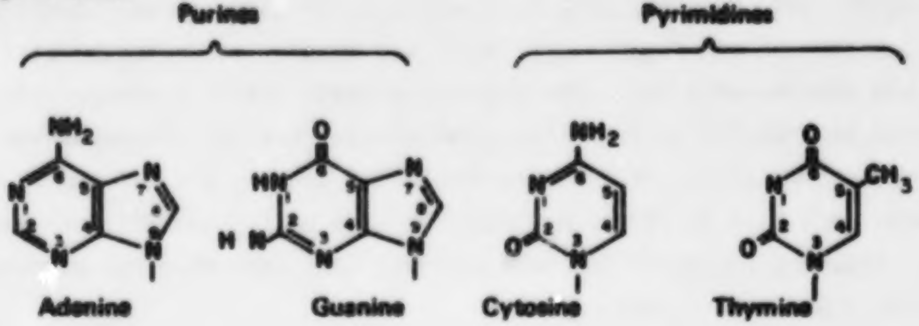
The cell is the basic unit of all living systems. Cell constituents include a containing membrane; the cytoplasm, or cell body, in which most of the metabolic functions are performed; and the nucleus, which contains the chromosomes. These chromosomes have been shown to command, either directly or indirectly, all the functions of cell metabolism. The following discussion of their structure and function is pertinent to chromosomes in higher order cells.

Chromosomes consist almost entirely of deoxyribonucleic acid, better known as DNA. It seems fairly clear that DNA is the active agent within the chromosomes that chemically orders the cell's functions. Specific actions of chromosomes are diverse and include: replication prior to mitosis; direct production of certain enzymes; and creation of unit lengths of ribonucleic acid (RNA) which then pass into the cytoplasm and induce the cell to perform its vital functions. This last role is the most important example of how DNA affects the cell's activities indirectly.

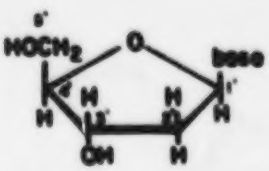
The chemical structure of DNA and RNA was made manifest in recent years by Watson and Crick who determined that DNA consists of two strands of nucleic acid which spiral around a common axis. This structure is often described as a "double helix". The unique architecture of the DNA molecule allows the chromosomal-DNA to duplicate itself exactly by splitting the two strands along the shared axis; each single strand then directs the reproduction of its complement. This duplication may be clearly understood after discussion of the chemical construction of nucleic acids.

Nucleic acids are comprised of phosphorylated sugars (deoxyribose in the case of DNA) and organic bases (adenine, thymine, guanine, and cytosine, in DNA). The sugar phosphates serve as connecting agents for the bases within a single strand of nucleic acid. The length of a nucleic acid chain is defined by the genetic needs of the individual cell. The structural units of the nucleic acid of DNA are shown in Figure G-1.

a) **Organic bases:**

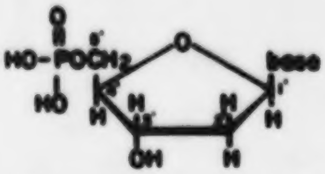

Purines
Pyrimidines
NH2
O
NH2
O
CH3
Adenine
Guanine
Cytosine
Thymine

b) **Nucleoside:**


5'
HOCH2
O
base
H
OH

2-deoxy-D-ribose (a sugar) substituted at the C-1 position by a heterocyclic base (from the four illustrated above).

c) **Nucleotide:**


O
HO-POCH2
HO
O
base
H
OH

The nucleoside phosphorylated in the ribose ring.

d) **Nucleic acid:**

Polydeoxyribonucleotide formed by polymerization deoxyribosonucleotide (the phosphate at the 3' sugar position is further esterified to the 5'-sugar position of its nearest neighbor).

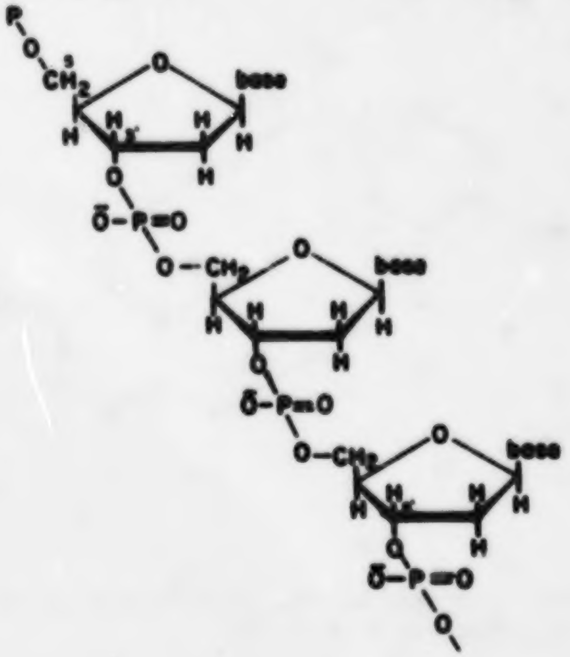

P
O
CH2
O
base
H
Ō-P=O
O-CH2
O-CH2
O

Figure G-2. The Structural Units of the Nucleic Acid of DNA

In DNA, two strands of polydeoxyribonucleic acid spiral together around a shared axis that is formed by the tendency of the organic bases to link to each other. The bases link, however, only in specific pairs under normal conditions; i.e., the bases adenine and thymine will pair, and guanine and cytosine will pair, but adenine and guanine will not. The sugar-base units within a single strand of nucleic acid may combine in limitless arrangements, but the corresponding bases in the matching second strand of the chromosomal-DNA are rigidly defined by the pairing effect; each base in strand A must be matched by its natural pair-mate in strand B. Figure G-2 reveals the bond patterns that determine the mandatory ordered pairing phenomenon in DNA.

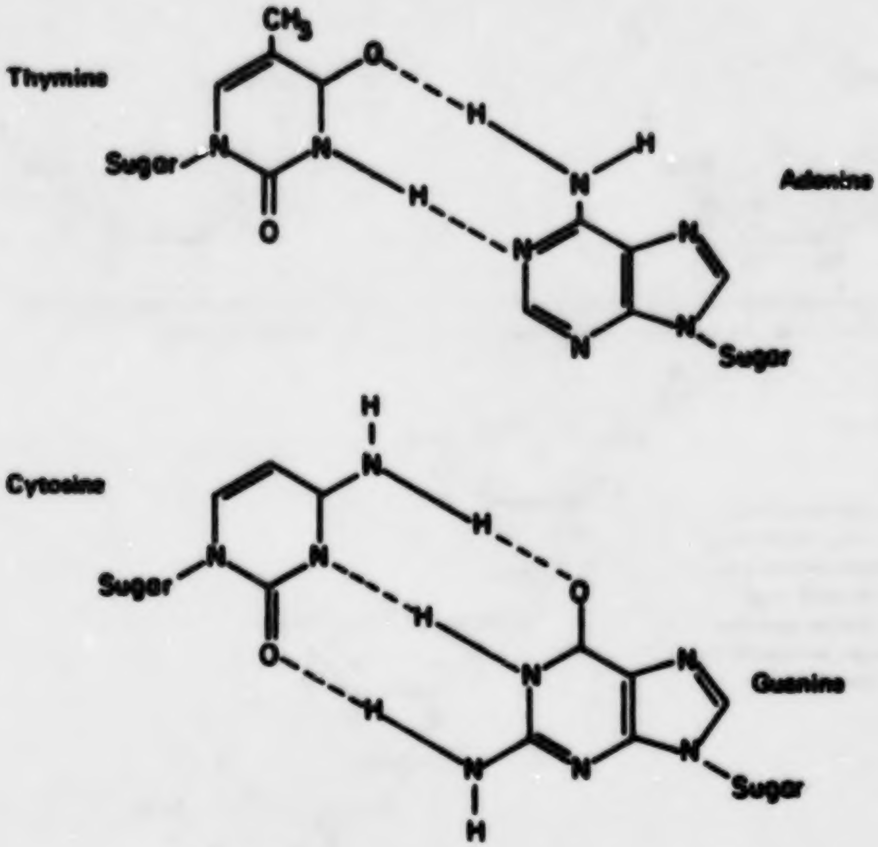

Thymine
CH_3
O
H
H
N
Sugar
N
N
H
Adenine
O
N
N
N
N
Sugar
H
N
Cytosine
H
Sugar
N
N
O
H
O
N
N
Guanine
H
N
N
N
Sugar
H

Figure G-2. Hydrogen Bonding Between Base Pairs of the Nucleic Acid of DNA

The structure of RNA is quite similar to DNA, except that in RNA the base thymine of DNA is replaced by the pyrimidine base uracil, and the sugar in the sugar-phosphate "backbone" is ribose instead of deoxyribose. One other difference is that RNA seems to occur in single strands. An accepted assumption is that segments of individual strands of chromosomal DNA order synthesis of complementary "messenger" RNA; the "messenger" passes into the cytoplasm and commands an individual specific cellular function.

It now seems clear that it is the pattern of the arrangement of the sugar-base units in DNA that determines the precise activities the cell is to perform. Each chromosome may be responsible for several activities; the segment of the chromosome which orders a specific function for the cell is known as a gene.

The relationship between these structural features of DNA and carcinogenicity is significant. If DNA, directly or indirectly, causes specific cell functions, then a change in DNA structure in a particular gene may be assumed to bring about a change in the cellular activity controlled by that gene. Several different types of chromosomal mutation have been studied as possible sources of carcinogenesis. The ability of chemical molecules introduced from outside the cell to react with and alter the complex molecules of DNA in specific ways has become the focal point of study in the field of chemical carcinogenesis.

There are several mechanisms (known or postulated) by which chemicals can cause alterations in DNA which may result in the formation of tumors.

Intercalation or insertion is an example of an important interaction between chemicals and DNA. It is known that polycyclic aromatic hydrocarbons (PAH), including those that are carcinogenic, are able to intercalate, as shown in Figure G-3, between the base pairs stacked in the center of the DNA molecule.

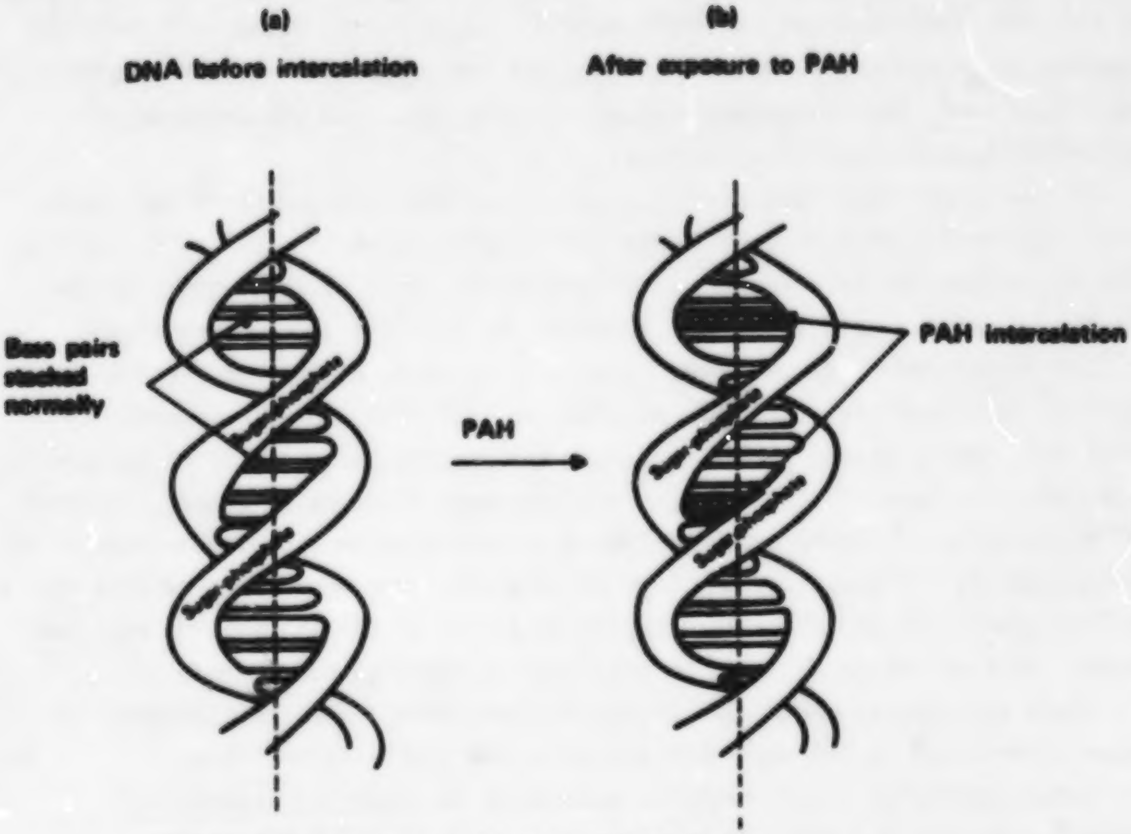
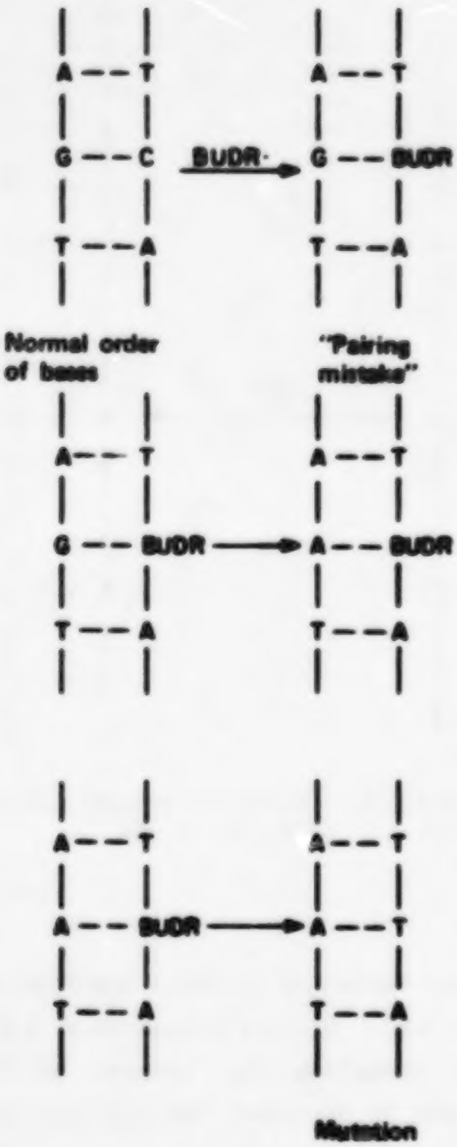

(a)
DNA before intercalation
(b)
After exposure to PAH
Base pairs stacked normally
PAH
PAH intercalation
Sugar phosphate
Sugar phosphate
Sugar phosphate
Sugar phosphate

Figure G-3. Intercalation of PAH in DNA

Both carcinogenic and non-carcinogenic PAH can wedge between the base pairs, but the physical complex formed by a carcinogenic PAH changes into a chemical complex when placed in a given hydroxylating system. No comparable conversion is observed with the complex formed by the non-carcinogenic PAH.

Chemicals can also bind to DNA by replacement of one of the bases. For example, as illustrated in Figure G-4, under certain conditions the compound 5-Bromodeoxyuridine (BUDR) can replace thymine (one of the bases) in DNA. The result is a mutation from a guanine-cytosine pairing in the DNA molecule to an adenine-thymine pairing. It is possible that other compounds react with DNA in a similar way.


A -- T
G -- C
T -- A
BUDR
A -- T
G -- BUDR
T -- A
Normal order of bases
"Pairing mistake"
A -- T
G -- BUDR
T -- A
A -- T
A -- BUDR
T -- A
A -- T
A -- BUDR
T -- A
A -- T
A -- T
T -- A
Mutation

a) BUDR replaces cytosine in DNA.

b) BUDR tends to pair with adenine.

c) BUDR is replaced by thymine; order of base pairs in DNA is altered.

Figure G-4. Mechanism for Mutation Caused by a "Pairing Mistake"

It is believed that changes in the conformation or spatial arrangement of DNA can also bring about mutations; certain bulky chemicals, for example, acetylaminoflorene (AAF) can bring about such conformation changes. Acetylaminoflorene (AAF) binds to the 8-position of guanine. The guanine then rotates around the bond that "hinges" it to the rest of the molecule to give a new conformation. Figure G-5 illustrates.

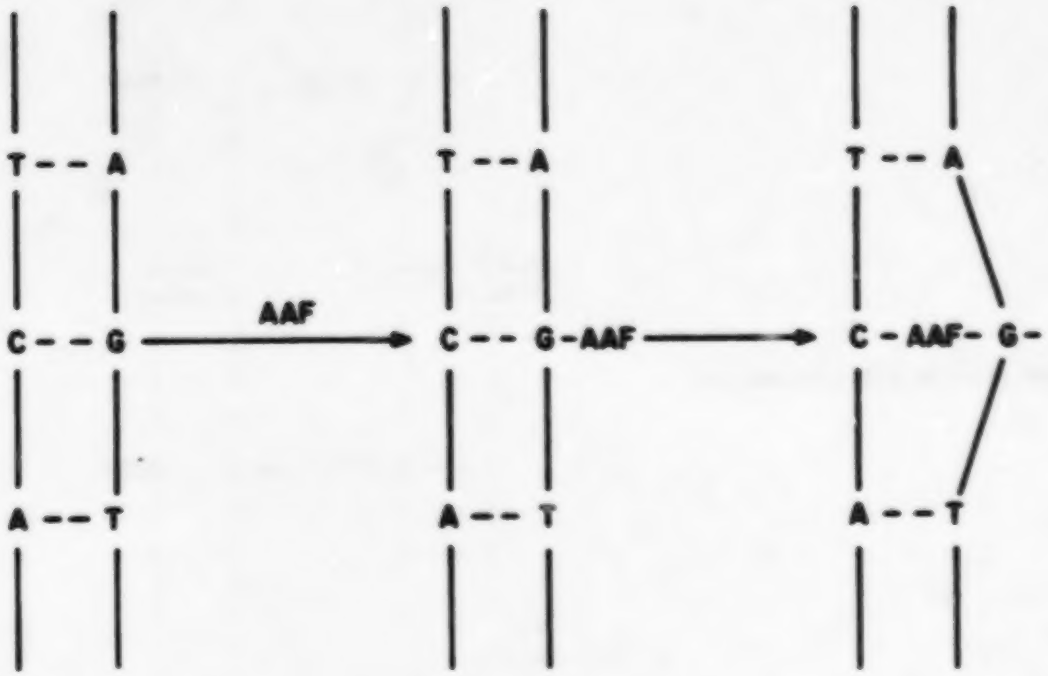


Figure G-5. Mechanism Whereby AAF Affects Conformation Changes in DNA

Another mechanism by which chemicals may affect DNA is crosslinking (shown in Figure G-6). Chemicals such as di and polyfunctional alkylating agents can react to crosslink the strands of DNA preventing the separation of the strands that is necessary for replication.

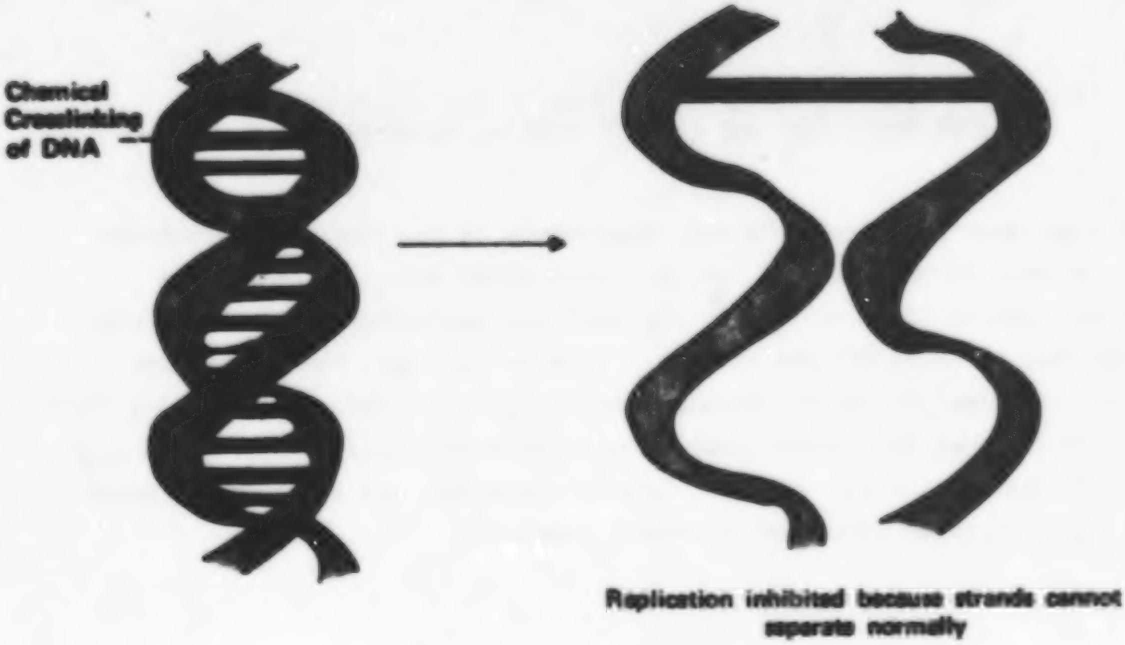

Chemical Crosslinking of DNA
Replication inhibited because strands cannot separate normally

Figure G-6. Crosslinking of DNA

Chemicals may also break the bond between guanine (a purine) and the sugar in the sugar-phosphate backbone of DNA; this is called depurination. The loss of guanine causes a gap in the DNA structure. If the DNA is replicated with such a gap, the mutation is called a deletion.

The idea that damage or alteration of DNA is part of the chain of events leading to cancer is a reasonable one, but a clear link between DNA damage and oncogenesis has not been conclusively demonstrated. It should also be pointed out that there are mechanisms by which the organism may repair DNA. In addition, it is important to recognize that many researchers believe that viruses are responsible for tumor induction. This idea, however, does not eliminate the role of chemicals in carcinogenesis since chemicals may, through alteration of DNA, bring about cellular changes that increase the susceptibility of the cell to viral attack.

POLYCYCLIC AROMATIC HYDROCARBONS (PAH) -- THE RELATIONSHIP OF CARCINOGENICITY AND PHYSICO-CHEMICAL PROPERTIES

PAH have been investigated by many researchers in an effort to distinguish the carcinogenic structures from the non-carcinogenic ones. No conclusive formula has come to light to provide the basis for prediction, but observations have been made which allow some insight. Table G-1 presents the conclusions resulting from some of the PAH structure/carcinogenicity studies. Table G-2 lists some of the theories and models advanced to explain the carcinogenicity of PAH along with observations and remarks. Several parameters and theories discussed apply as well to other carcinogenic organic compounds.

TABLE G-1. SUMMARY OF PHYSICO-CHEMICAL PROPERTIES OF POLYCYCLIC AROMATIC HYDROCARBONS AND THEIR RELEVANCE TO CARCINOGENESIS

Molecule Size	Apparent optimum size for PAH carcinogens = $120 Å^2$. Very large PAH are not carcinogenic. There seems to be a limit to the size of a molecule beyond which it cannot induce cancer.
Thickness	This has been studied in more detail with heterocyclic compounds, but there seems to be a limit to the thickness of a molecule for proper "fit".
Planarity.	PAH carcinogens are planar. Deviations from planarity reduce carcinogenicity.
Conjugation	Reduction (by partial hydrogenation) of the maximum number of cumulative double bonds in a PAH structure reduces carcinogenicity.
Symmetry.	It has been suggested that carcinogenic activity is more frequent in compounds with asymmetric geometry. Not specific.
Substituents	Size and position of substituents modify carcinogenicity.
Molecular Weight	Most carcinogens have molecular weights below 500.
Volatility	PAH hydrocarbons may be sublimed. Important in transport of particle in the atmosphere.
Solubility a) water. .	PAH (carcinogenic and non-carcinogenic) are insoluble in water, may be solubilized by impurities in water. Solubilization can be important in transport of molecule in organisms.
b) lipid. .	Solubility of PAH (carcinogenic an non-carcinogenic) in lipids vary. As membranes of cells contain lipi it may be important in transport o molecules or by virtue of interaction with membrane.
Fluorescence	Many PAH carcinogens exhibit fluorescence. Not specific.
Photodynamic activity. . .	Many PAH exhibit photodynamic activity. Not specific.

TABLE G-2. SUMMARY OF THEORIES OR MODELS ADVANCED TO EXPLAIN CARCINOGENICITY OF POLYCYCLIC AROMATIC HYDROCARBONS (PAH)

Theory or model	Observation	Remarks
a) Physical interaction	PAH intercalate between base-pairs in molecules of DNA.	Not selective. Both carcinogenic and non-carcinogenic PAH interact in a physical way with molecules of DNA.
b) Chemical bonding	Certain PAH in hydroxylating solvent system bind chemically to DNA.	Selective. B(a)P (carcinogenic) in an activating solvent system binds chemically to DNA, B(e)P (non-carcinogenic) in same system does not.
c) Cationic radical	Cationic radicals of PAH are readily formed and react with some organic bases.	Not selective. Cation radical of DMBA (carcinogen) reacts with purine; cation radical of perylene (non-carcinogen) also reacts with purine.
d) K-region epoxide - (cyclic oxide formed at a strongly olefinic bond in a polycyclic aromatic hydrocarbon)	a) K-region epoxides of carcinogenic PAH are more active in inducing malignant transformations "in vitro", than parent compound. b) K-region epoxides react chemically with nucleic acids while parent hydrocarbon does not. c) A direct relationship has been recognized between mutagenicity of K-region epoxides in bacteriophage and carcinogenicity of parent hydrocarbon.	Evidence indicates K-region epoxides are important in the metabolism of carcinogenic PAH to the ultimate carcinogen.
e) Role of aryl hydrocarbon hydroxylase	This enzyme is present in tissue of many species, including man. This enzyme catalyzes formation of B(a)P metabolite that binds to DNA. Correlation has been established between susceptibility to lung cancer and presence of the enzyme.	In animals exposed to PAH (carcinogenic and non-carcinogenic) the level of enzyme increases. Considered important in the activation of PAH to their carcinogenic form.

TABLE G-2. (continued)

Theory or model	Observation	Remarks
f) Role of oxy-radical	B(a)P (carcinogen) is converted to the free radical 6-oxy-benzopyrene by incubation with rat liver homogenates. The free radical binds to DNA in vitro.	Considered more important than cationic radicals. The binding of a precursor of the oxy-radical to DNA changes from physical to chemical without addition of an activator
g) Electrophilic reactant	Most carcinogens are believed to be electrophilic (electron-seeking).	Experimental evidence indicates, ultimate carcinogen of PAH is likely to be an electrophile.
h) Carcinogens as "tissue burden".	Many known chemical carcinogens are found in tissues years after last exposure to agent.	Rate at which a chemical bound to DNA is removed may be important in initiation of cancer. The reaction of compound with enzymes to form soluble compounds that are then eliminated from the system is one known mechanism of detoxification.

METALS AND CARCINOGENESIS

The mechanisms of carcinogenesis presented so far in this appendix have been mainly associated with the action of organic compounds in cellular material. Comparable theories and patterns have not been proposed to explain the carcinogenicit of certain metals. There is, however, a great deal to be said about metals and their roles in biochemistry. The brief discussion that follows addresses binding by metals and ways in which they might affect living cells. The behavior of metals within biomolecules is highly relevant to carcinogenesis. Metallic ions bind in an organism by a) electrostatic forces and b) by coordination to specific sites in proteins or nucleic acids.

Electrostatic forces describe the reciprocal attraction of an ion (or polar molecule) with a positive charge for an ion (or polar molecule) with a negative charge. A Na^+ ion, for example, will be attracted to negative sites in a cell membrane. Another example of electrostatic bonding is the bonding of Mg^{++} to adenosinetriphosphate (ATP); the metallic ion can be displaced with ease. Univalent metal ions (Na^+, K^+) and some divalent metal ions (Ca++, Mg++) move rather freely wit the organism and some ions can permeate cell membranes. Ions such as these that move easily within organisms are loosely held and are not implicated in carcinogenes

The metals that can induce tumors in experimental animals all have the ability to form coordination compounds. Coordination compounds are comprised of a metal and a coordinating agent. Almost any group (ion or molecule) having an unshared pair or electrons can act as a coordinating agent. Biomolecules like proteins, phospholipids, carbohydrates, and nucleotides all have coordinating groups to which metal ions can bind. Some examples are the nitrogen of histidine, the NH_2 of lysine and other amino acids, the nitrogens of purine and pyrimidine bases, the oxygen of hydroxy functions as in serine, the PO_4^{-3} of phospholipids, and the sulfur of thiol groups (as in cysteine).

Coordinating groups arrange about a metal ion in a special way depending on the coordination number of the metal. A metal ion with coordination number of four can exhibit a pyramidal or a square-planar configuration. For example, the compound $Pt(NH_3)_2Cl_2$ is known to assume a square planar configuration with the platinum metal at the center and in the same plane as the coordinating groups. The coordinating groups may assume positions at the corners of the square in either of two configurations. If two identical groups are adjacent to one another, the configuration is called "cis." If they are opposite, it is called "trans." Cis and trans configurations may affect an organism in totally different ways.

When a group can coordinate simultaneously at two or more places it is called a chelate. One important chelated structure occurring in organisms is that of the metalloporphyrin. Hemoglobin is an example of such a compound; it is an iron (II) porphyrin. The structure of many metalloporphyrins is planar, but in some divalent metal porphyrins the metal is slightly above the plane, and the resulting arrangement is more like a pyramid.

Other coordinating arrangements are also possible. For example, the arrangement of coordinating groups about a metal with a coordination number of six is indicated by X-ray and other experimental evidence to be octahedral. The binding of Cu (II) to base pairs in DNA also represents an octahedral arrangement.

The arrangement of groups about a metal determine in part:

(a) the ease with which the metal can participate in a reaction; and

(b) whether the metal can be easily substituted by another metal.

Metals in chelated structures are held tightly, and therefore, displacement, when it occurs, can be expected to force the coordinating groups into an altered arrangement or conformation.

Since most metals in organisms are associated with proteins and enzymes which require specific structures to be biologically active, it is clear that displacement of a metal within these chelated biomolecules can alter the normal processes of an organism by changing a specific molecular conformation.

It is reasonable to suspect that changes in the normal processes of an organism can increase the susceptibility of that organism to cancer.

Other ways by which a metal can alter the natural processes in an organism include:

1) altering the permeability of membranes.
2) binding to specific residues, thus blocking necessary cellular reactions. (For example, heavy metals can bind to the sulfur in the SH group of cysteine blocking that site for enzymatic reactions.)
3) inhibiting certain processes. (For example, Be (II) inhibits the synthesis of DNA.)

SHORT TERM BIOASSAYS

The only criterion generally accepted as a test for carcinogenesis is the induction of tumors in experimental animals or man. However, the growing number of known chemicals makes this approach increasingly difficult. The cost of screening a single compound by conventional methods has been estimated at a hundred thousand dollars. Interest in the development of short-term tests for carcinogenicity stems not only from the cost and duration of animal testing but from the urgent need to identify potential carcinogens before the population is exposed to them. Proponents of short-term testing point to the fact that the detection of carcinogenicity by animal bioassays is limited by the variations in sensitivity of the different species and the inability of such tests to detect the induction of tumor incidence below 10 percent. Also, large-scale, long-term tests in animals are not free from galse negatives.

Most short-term tests depend on the mutation of cells. The basis for the mutation-cancer correlations is the assumption that certain mutations (changes) in a somatic cell increase the probability that the cell will transform into a cancerous cell.

Short-term tests to detect mutagenicity (as an indication of carcinogenicity) have been carried out using: a) bacteria, b) yeast or fungus, c) Drosophila (fruit-fly), and d) mammalian cells. These short-term mutagenicity (implied carcinogenicity) tests are briefly described below. Currently, there is a need for all the tests for carcinogenesis to mimic more effectively the action in a living organism.

TESTS USING BACTERIA -- AMES TEST

A widely used short-term bioassay is the one known as Ames Test; developed by Dr. Bruce Ames of the University of California at Berkeley.

The indicator in the Ames test consists of special strains of mutants of Salmonella typhurium (a bacteria) in appropriate culture media. The culture media usually contain liver microsomes whose function is to activate the carcinogens

The suspected carcinogen is placed on the indicator gel in a petri-dish and the growth of the revertant bacteria around the spot indicates a positive reaction. (The indicator bacteria can grow on the culture media only if a back-mutation is induced by the chemical, allowing the revertant bacteria to multiply in the culture media.)

The Ames test is fast and inexpensive but not without shortcomings. The test is not considered suitable for metal carcinogens and promoters, because of the large amount of magnesium citrates, and phosphates required in the medium. Also, developers of the test admit that the test has a history of 15 percent false negatives and 10 percent false positives. Opponents of the test consider that 15 percent of false negatives is too high to make the Ames test alone of value for screening compounds for carcinogenicity.

The test for mutagenicity using bacteria is perhaps the simplest but is also the one farthest removed genetically from the cells where cancer actually occurs. There is a need for tests that can detect different forms of genetic damage or for tests that complement the information obtained from other tests.

MODIFIED BACTERIA -- HOST MEDIATED ASSAY

A modified bacterial test is the host-mediated assay. In this test, an animal is used as host and pre-treated with the suspected carcinogen to be tested. Then a strain of mutant bacteria is injected into the peritoneal cavity. After a short period of time, the animal is sacrificed and revertant or back-mutant bacteria are counted.

TESTS USING YEASTS

In man, the genes associated with increased susceptibility of the cell toward transformations are recessive although there are genetic mechanisms by which the recessive properties may "surface". In cells of lower organisms, recessive properties may become dominant by mitotic recombination and gene conversion. These two mechanisms (not yet confirmed to occur in man) can be quantitavely studied in yeast. It has been suggested that bio-assay with yeasts be included in any battery of tests for carcinogenicity.

TESTS USING DROSOPHILA

Drosophila (fruit fly) is a complex organism used often for mutagenic studies. It is composed of specialized tissue and organs and reproduces by sexual means only.

The mutagenic studies using Drosophila involve the detection of sex-linked lethals (combination of chromosomes that result in death for the offspring). The sex-linked lethal characteristic can be recessive or dominant.

To detect dominant lethal mutations, male flies are treated with a chemical and mated with untreated females. If the chemical induces a dominant lethal mutation, the eggs that inherit a dominant lethal chromosome will not hatch. The ratio of unhatched eggs from such matings as compared to controls gives a measure of the frequency of mutations. To detect recessive trait mutations, special female tester strains with bar-shaped, apricot color eyes are allowed to mate with males that have been exposed to the chemical being tested. After females of the first generation are crossed with males of the first generation, a statistical study of the sex and type of eyes in the second generations indicates whether or not the chemical caused mutation.

There are distinct advantages to using Drosophila in screening chemicals for carcinogenic properties. In contrast with other test systems where only one class of genetic damage can be studied, special strains of Drosophila permit the simultaneous study of a variety of genetic changes. Also, Drosophila has capacity for metabolic activation (i.e., procarcinogen is converted to an active form).

USE OF MAMMALIAN CELLS

Mammalian cells compared to bacteria are more difficult to grow in tissue culture, and their mutation is more complex to interpret. To allow the use of mammalian cells in carcinogen testing, strains of cells that are azaguanine resistant (Azg^r) or azaguanine sensitive (Azg^s) have been developed from Chinese hamsters. The reversibility induced by mutations allows their use as a test of mutagenicity.

$$\mathrm{Azg}_r \quad \underset{\text{Mutant}}{\overset{\text{Mutant}}{\rightleftarrows}} \quad \mathrm{Azg}_s$$

(grow in azaguanine) (do not grow in azaguanine)

For the test, Azg_s cells are treated with the chemical to be tested for a given period of time. The cells are then washed to remove all traces of the chemical and recultured in fresh medium. When azaguanine is then added, only the cells that have changed from Azg_s to Azg_r will grow, giving an indication of the mutagenicity of the chemical.

Hybrid cells from Chinese hamster cells and human cells are being developed. In these hybrid cells, most of the human chromosomes are lost, but hybrid cells with even one human chromosome are expected to be very valuable in the study of carcinogenesis.

APPENDIX G

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APPENDIX H

GLOSSARY

GLOSSARY

aberration (chromosome): An irregularity of chromosomes that causes a duplication, deletion, exchange, or other alteration of the genetic material.

absorption factor: The percentage of an available substance normally assimilated by a life form through an inhalation or ingestive process under known conditions; usually expressed as a decimal figure.

acid hydrolysis: Dissociation of molecules into ions in the presence of acids.

acid mine drainage: Drainage of water carrying dissolved substances that cause lowering of pH to 2-4.5; not only are the dissolved compounds potential pollutants, but the lowered pH induces increased solubility of heavy metals within the stream.

acne: Dermatitis caused by inflammation of sweat glands and hair follicles.

acute exposure: A single exposure of short-term duration.

acute toxic effect: A reaction to exposure of short-term duration which results in immediate effects that last for a short duration with little tissue reaction.

adipose: Fatty; pertaining to fat-storing connective tissue in animals.

adjusted ordering number: See dosage adjusted ordering number.

aerobic: Description of biological or chemical processes that can occur only in the presence of oxygen.

Preceding page blank

aerosol: Any of several types of dispersions of solid or liquid particles of microscopic size in a gaseous medium.

agglomerate: To gather into a mass, or cluster.

albuminuria: The presence of blood albumin in urine.

alkyl (group): A structural unit of organic molecules comprised of C_nH_{2n+1} (examples are methyl, ethyl, propyl, etc.)

allergin: An agent that induces allergy.

allotrope: An alternative physical form of a substance (esp. an element) in the same phase (e.g.,crystals and amorphous powder).

alum: As a general term, any of various double salts isomorphous to potassium aluminum sulfate.

Ambient Level Goals: Levels of contaminants in air, water or land which will not adversely affect human health or the ecology, continuous exposure assumed.

anaerobic: Description of biological or chemical processes that can occur only in the absence of oxygen.

anemia: A deficiency of oxygen transport ability of blood.

anesthetic: Any substance or action that results in loss of neurosensation.

anion: Any negatively charged ion.

antagonism: An interaction of two or more substances such that the usual action of any one of them on living cells or tissue is altered.

antioxidant: An agent that inhibits oxidation.

application factor: Usually, the ratio of a safe concentration of a substance to its lethal concentration; other ratios may also be defined and called application factors.

aromatic (compound): Usually an organic compound containing an aromatic homocyclic or heterocyclic ring.

asphyxiation: A condition in which the useable oxygen supply is limited due to the presence of another chemical.

autooxidation: An oxidation reaction that occurs spontaneously in the presence of air.

background concentration level: The normally occurring concentration level of a substance in a given environment and medium (see "natural background").

bacteria: One cell plants with no chlorophyl that multiply by cell division.

BAT: See best available technology.

benthic (organism): Of or occuring in the depths or at the bottom of a body of water.

best available technology (BAT): That set of plant processes judged to perform best among those functionally and economically viable.

best practicable technology (BPT): The set of end-of-process industrial controls judged to perform best in the context of maximum results weighed against feasible cost.

biochemical oxygen demand (BOD): The oxygen required to meet the metabolic needs of aerobic microorganisms in water rich in organic matter; most often used to measure the amount of organic matter in wastewater.

biodegradable: Having the ability to breakdown or decompose rapidly under normal environmental conditions and processes.

biological half-life: The amount of time required for half the amount of a substance in or introduced into a living system to he eliminated by natural processes.

BOD: See biochemical oxygen demand.

botryococcus: A bacterium.

BPT: See best practicable technology.

camphor: Generally, any of several compounds similar to the fragrant derivative of the camphor tree, $C_{10}H_{16}O$, with its characteristic odor.

carbonaceous: Of, relating to, composed of, or rich in carbon.

carcinogen(ic): An agent which is capable of producing cancer in a tissue upon exposure.

carcinoma: A malignant, cancerous tumor involving skin or interior protective tissue (epithelial tissue).

catalyst: An agent that initiates and/or modifies a chemical reaction; esp. its rate, yet itself remains unchanged at the completion of the reaction.

cell: The elementary living unit of all organisms.

chemical half-life: The time required for decomposition or removal of one half the mass of a substance from a medium; mechanisms of removal include both chemical reactions and physical influences.

chemical oxygen demand (COD): The oxygen equivalent of any organic matter subject to oxidation by a strong chemical oxidant; used as a measurement of organic pollution in wastewater.

chlorination: The reaction of a chemical with chlorine or the addition of chlorine or chlorine-bearing compounds to water supplies for the purpose of disinfection.

chronic exposure: Prolonged or repeated exposure over a long-term duration.

chronic toxic effect: A reaction to exposure which results in prolonged effects characterized by pathological tissue changes for which little or ineffective repair is possible, or which continue to worsen.

co-carcinogen: An agent, not itself a carcinogen, which enhances the action of a given carcinogen when present in an administered mixture with that carcinogen.

COD: See chemical oxygen demand.

colloid: A substance in suspension that cannot pass through a semi-permeable membrane, whose particles are too small for resolution with an ordinary light microscope, which will not precipitate, but will detract a beam of light.

conjunctivitis: Inflammation of the membrane lining the eyelid.

corneal: Of or relating to the cornea, the transparent protective surface covering the front part of the eye.

cumulative (or bio-accumulative): A toxicant having a biological half-life greater than 30 days, thus tending to allow accumulation, especially within a functioning life system.

cyanosis: A bluish or purplish discoloration resulting from oxygen deficiency.

Daphnia (magna and sp.): Species of water flea used in evaluating toxicity of water-borne contaminants.

declination: A turning or bending, especially downward.

decomposition (microbial): Chemical breakdown caused by microbial metabolic processes.

degradation: A decrease in chemical complexity; decomposition.

depressant: An agent that reduces bodily functional activity, especially the central nervous system.

dermatitis: Inflammation of the skin.

detoxify: To remove a poison or relieve its effect.

dilution factor: The ratio of the concentration of a pollutant in an emission or effluent to the concentration of the pollutant resulting in the ambient medium of the vicinity after dispersion of the pollutant.

dissolved oxygen (DO): The concentration of dissolved oxygen in water, usually expressed in parts per million or percentage of saturation.

dissolved solids: Solids present in solution.

(dosage-)adjusted ordering number: An indicator of relative carcinogenic hazard potential; the EPA/NIOSH ordering number divided by the lowest dose (in mg/kg) reported to result in an oncogenic response in a test subject.

Drosophila: Any of several insects known as fruit flies; commonly used in genetic research and in bioassays for mutagens (and carcinogens).

dusts: Solid particles generated by physical processes (handling, crushing, grinding, impact, detonation, decrepitation) involving organic or inorganic materials; usually flocculate only under electrostatic forces; do not diffuse in air, and will settle under the influence of gravity.

ecology: The science of the intricate web of relationships and interactions between living organisms and their living and nonliving surroundings.

edema: A swelling, caused in animals by an accumulation of serous fluid in connective tissue or in a serous cavity.

effluent: The waste discharge, especially water, from a point source into the surrounding media.

electrophilic: Having an affinity for, or attraction to, electrons.

Elimination of Discharge Goals: Emission level goals which seek to limit pollutant concentrations in emissions or effluents to the natural background levels.

Emission Level Goals: Desired levels of contaminants in emissions or effluents from a point source.

enzyme: A protein that acts in a highly specific manner as a catalyst in a biochemical reaction.

EOD: See elimination of discharge

EPA/NIOSH ordering number: An arbitrarily derived four-digit number designed to order in terms of their relative hazard potential the substances appearing in the NIOSH Suspected Carcinogens List based on information included in the List; considers species of animals responding and route of administration used in whole animal bioassay of chemical carcinogens.

EPC_{AC} (expressed in $\mu g/m^3$): $EPC_{air,\ carcinogenicity}$. The estimated permissible concentration of a chemical substance in air based on the potential carcinogenicity of the substance. This concentration represents a "minimal risk" level, rather than a "no-effect" level.

EPC_{AC1} (expressed in $\mu g/m^3$): The estimated permissible concentration (minimal risk concentration) of a chemical substance in air based on the TLV established for the chemical recognizing its potential carcinogenicity. $EPC_{AC1} = 10^3 \times TLV\ (mg/m^3)/420$.

EPC_{AC2} (expressed in $\mu g/m^3$): The estimated permissible concentration (minimal risk concentration) of a chemical substance in air based on the carcinogenic potential of the substance as indicated by its adjusted ordering number. $EPC_{AC2} = 10^3/(6 \times \text{adj. ord. number})$.

EPC_{AE} (expressed in $\mu g/m^3$): $EPC_{air,\ ecology}$. The estimated permissible concentration of a chemical substance in air based on potential effects of the chemical substance on the ecology, especially vegetation. $EPC_{AE} = 100 \times$ lowest 24 hour concentration or equivalent reported to result in an effect in sensitive plant species (mg/m^3).

EPC_{AH} (expressed in $\mu g/m^3$): $EPC_{air,\ health}$. The estimated permissible concentration of a chemical substance in air based on potential effects of the substance on human health.

EPC_{AH1} (expressed in $\mu g/m^3$): The estimated permissible concentration of a chemical substance in air based on a model utilizing TLV's (other than those recognizing carcinogencity) established by the ACGIH. $EPC_{AH1} = 10^3 \times TLV\ (mg/m^3)/420$.

EPC_{AH1a} (expressed in ppm): Same as EPC_{AH1} expressed in ppm.

EPC_{AH1a} = TLV (ppm)/420.

EPC_{AH2} (expressed in $\mu g/m^3$): The estimated permissible concentration of a chemical substance in air based on the LD_{50} for the chemical and utilizing the relationship between LD_{50}'s and TLV's described by Hendy and Schindler. $EPC_{AH2} = 0.107 \times LD_{50}$ (mg/kg).

EPC_{AH3} (expressed in $\mu g/m^3$): The estimated permissible concentration of a chemical substance in air based on the LD_{50} for the chemical and considering accumulation and safe body burden. A 30 day biological half-life is assumed. $EPC_{AH3} = 0.081 \times LD_{50}$ (mg/kg).

EPC_{AHS} (expressed in $\mu g/m^3$): The estimated permissible concentration of a chemical substance corresponding to the most stringent existing Federal regulation prescribing an air concentration for the chemical based on human health considerations.

EPC_{AT} (expressed in $\mu g/m^3$): $EPC_{air,\ teratogenicity}$. Same as EPC_{AC2} except that adjusted ordering number is based on teratogenic potential. $EPC_{AT} = 10^3/(6 \times \text{adj. ord. number})$.

EPC_{LC} (expressed in $\mu g/g$): $EPC_{land,\ carcinogenicity}$. The estimated permissible concentration of a chemical substance in land based on potential carcinogenic effects resulting from exposure to water contaminated through leaching of the chemical substance from soil. It is assumed that two liters of water are capable of leaching the chemical substance from one kg of soil. $EPC_{LC} = 0.002 \times EPC_{WC}$ ($\mu g/\ell$).

EPC_{LE} (expressed in $\mu g/g$): $EPC_{land,\ ecology}$. The estimated permissible concentration for a chemical substance in land based on potential ecological effects resulting from exposure to water contaminated through leaching of the chemical substance from soil. It is assumed that two liters of water are capable of leaching the chemical substance from one kg of soil. $EPC_{LE} = 0.002 \times$ lowest EPC_{WE} ($\mu g/\ell$).

EPC_{LH} (expressed in μg/g): $EPC_{\text{land, health}}$. The estimated permissible concentration of a chemical substance in land based on potential human health effects other than genotoxic effects resulting from exposure to water contaminated through leaching of the chemical substance from soil. It is assumed that two liters of water are capable of leaching the chemical substance from one kg of soil. $EPC_{LH} = 0.002 \times$ lowest EPC_{WH}(μg/ℓ).

EPC_{LT} (expressed in μg/g): $EPC_{\text{land, teratogenicity}}$. Same as EPC_{LC} except based on EPC_{WT}. $EPC_{LT} = 0.002 \times EPC_{WT}$.

EPC_{WC} (expressed in μg/ℓ): $EPC_{\text{water, carcinogenicity}}$. The estimated permissible concentration (minimal risk concentration) of a chemical substance in water based on the EPC_{AC} for the substance. It is assumed that a minimal risk dosage results from 24-hour exposure to air containing the EPC_{AH} concentration and that the same dosage is therefore permissible in the volume of drinking water consumed in 24 hours. $EPC_{WC} = 15 \times EPC_{AC}$ (μg/m^3).

EPC_{WE} (expressed in μg/ℓ): $EPC_{\text{water, ecology}}$. The estimated permissible concentration of a chemical substance in water based on potential effects of the chemical on ecology, i.e., aquatic life.

EPC_{WE1} (expressed in μg/ℓ): The estimated permissible concentration of a chemical substance in water based on the lowest reported LC_{50} or TLm for sensitive aquatic species and assuming an application factor of 0.05. $EPC_{WE1} = 50 \times$ lowest reported 96-hour TLm or LC_{50} (mg/ℓ or ppm).

EPC_{WE2} (expressed in μg/ℓ): The estimated permissible concentration of a chemical substance in water based on the lowest concentration of the chemical reported to cause tainting in fish flesh. EPC_{WE2} = lowest level causing fish tainting (μg/ℓ).

EPC_{WE3} (expressed in μg/ℓ): The estimated permissible concentration of a chemical substance in water based on the lower value derived from either of two models: (1) the product of the application factor (as recommended in existing or proposed Federal water criteria) times the lowest reported 96 hour TLm or LC_{50} for a sensitive aquatic species. EPC_{WE3} = application factor × lowest TLm (μg/ℓ); or, (2) the product of the hazard level (as recommended in existing or proposed Federal water criteria established for protection of aquatic life) times an arbitrary factor of 0.2.
EPC_{WE3} = hazard level (μg/ℓ) × 0.2.

EPC_{WE4} (expressed in μg/ℓ): The estimated permissible concentration of a chemical substance in water based on the maximum allowable concentration of the substance in aquatic life and the biological accumulation factor:

$$EPC_{WE4} = \frac{\text{Max. allowable conc. } (\mu g/kg)}{\text{Concentration factor}}$$

EPC_{WES} (expressed in μg/ℓ): The estimated permissible concentration of a chemical substance corresponding to the most stringent existing or proposed Federal water criteria established for the protection of aquatic life or to prevent injury to plants.

EPC_{WH} (expressed in μg/ℓ): $EPC_{water,\ health}$. The estimated permissible concentration of a chemical substance in water based on potential effects of the substance on human health.

EPC_{WH1} (expressed in μg/ℓ): The estimated permissible concentration of a chemical substance in water derived from the assumption that a maximum daily safe dosage results from 24-hour exposure to air containing the EPC_{AH} of the chemical (assuming 100 percent absorption) and that the same dosage is therefore permissible in the volume of drinking water consumed in 24 hours.
EPC_{WH1} = 15 × lowest EPC_{AH}(μg/m^3).

EPC_{WH2} (expressed in µg/ℓ): The extimated permissible concentration of a chemical substance in water based on considerations of the safe maximum body concentration and the biological half-life of the substance. $EPC_{WH2} = 13.8 \times TLV\ (mg/m^3)$ or if TLV unavailable $EPC_{WH2} = 0.4 \times LD_{50}\ (mg/kg)$.

EPC_{WHS} (expressed in µg/ℓ): The estimated permissible concentration of a chemical substance corresponding to the most stringent existing or proposed Federal regulation or criteria prescribing a water concentration for the chemical based on human health considerations.

EPC_{WT} (expressed in µg/ℓ): $EPC_{water,\ teratogenicity}$. Same as EPC_{WC} except based on the EPC_{AT}. $EPC_{WT} = 15 \times EPC_{AT}(\mu g/m^3)$.

epidemiology: The study of the incidence, distribution, and control of disease in a population.

epinasty: The abnormal bending of a plant part caused by excessive growth of one surface.

Estimated Permissible Concentration (EPC): The estimated level of a substance for continuous exposure that will not result in toxic effects to humans or to the ecology.

estuaries: Partially enclosed [by land] bodies of water subjected to tidal flux located at the interface between land and ocean; they are a mixture of both ocean and fresh waters, e.g. the lower courses of rivers with ocean outfalls, and coastal sounds.

eutrophication: The natural aging process of a relatively contained body of water, in which aquatic life forms progress through several stages to densities that deplete the supply of dissolved oxygen, eventually leading to vegetable forms that fill the containing land form; the process is greatly enhanced by the introduction of foreign pollutant substances (especially phosphorus and nitrogen) that nurture aquatic growth.

fibrosis: A condition marked by an increase of interstitial fibrous tissue.

floc: A mass formed by the aggregation of fine suspended particles.

floc density: The apparent density of a flocculent mass; generally a very low value in comparison to the density of the specific constituents of the mass.

fugitive emission: An undesirable, uncontrolled non-point source emission or effluent.

fumes: Solid particles generated by condensation from the gaseous state, generally after volatilization from melted substances and often accompanied by a chemical reaction; will flocculate or occassionally coalesce [Note: Popular usage sometimes includes any type of contaminant.]

fusel oil: An acrid, oily liquid occurring in insufficiently distilled alcoholic liquors, consisting chiefly of amyl alcohol; used as a source of alcohols and as a solvent.

gas bubble disease: A physical reaction in fish exposed to abnormal concentrations or pressures of gases in water, characterized by the formation of gas bubbles both on the organism and within its system and leading to death by asphixiation induced by blockage of the circulatory system by gas emboli.

genes: Units of chromosomes that determine and mediate heredity.

genotoxins: Chemical substances that affect genes. Used to refer to those agents reported to be oncogenic, teratogenic, or mutagenic.

gestation: Period of embryonic development within a mammalian uterus.

halogenation: A chemical reaction involving the addition or substitution of halogen anions (F^-, Cl^-, Br, I^-) on a compound.

hectare: A metric unit of area equal to 10,000 square meters or 2.471 acres.

hematuria: The presence of blood or blood cells in urine.

hemoglobin: An Iron (II) porphyrin compound which binds oxygen; found in mammalian red blood cells.

hemolysis: Disintegration of red blood cells.

hemolysin: An agent that causes the disintegration of red blood cells.

hemorrhagic nephritis: An acute inflammation of the kidney with resultant uncontrolled heavy bleeding.

hepatoma: A tumor, usually malignant, of the liver.

homolog: Any of several similarities of structure, ranging from membership in the same group of the periodic table to a regular progression within a chemical series (e.g. of added CH_2 groups).

hydrogenation: A form of chemical reduction in which hydrogen reacts with a chemical substance.

hydrology: The science of water; deals with the properties, distribution, and circulation of water on and beneath the earth's surface and in the atmosphere.

hydrolyze: Chemical decomposition involving splitting a bond and addition of the elements of water.

hygroscopic: Attracting and retaining water.

hypersensitivity: Abnormally susceptible, to an antigen, drug or other agent.

hypothermia: Subnormal body temperature.

innocuous: Harmless; without adverse effect.

in situ: In natural or original position.

intraperitoneal: Within the peritoneal cavity, or through the peritoneum; i.e., within the cavity containing the abdominal viscera.

intravenous: Within or into a blood vein.

in vacuo: In a vacuum.

in vivo: In life; in the living organism.

ion: A free electron or other charged particle, formed by the addition or subtraction of electrons.

ionic radius: The measurement in Angstrom units (1 Angstrom = 10^{-8} cm) of the radius of a charged atom when considered as a spherical body.

isomer: A compound, or ion with specific atoms numbering the same as the atoms in another compound or ion, but with a different structural arrangement or charge.

isotope: Alternate form of an element caused by difference in the number of neutrons; isotopes have the same atomic number (number of protons) but different atomic weights.

lacrimation: The secretion of tears, especially in excessive amounts.

land dispersion: The diffusion or scattering of pollutants or source emissions (especially solid wastes) on land or the diffusion of substances within soil from higher concentrations to lesser concentrations.

LC_{Lo}: The lowest concentration of a substance in air or water, reported to cause death in a human or animal. (The Lo may or may not be subscripted.)

LC_{50}: The calculated concentration of a substance in either air or water (as separate figures) which will cause the death of 50 percent of an experimental animal population under controlled conditions and time exposure, most often 96 hours for aquatic species. (The 50 may or may not be subscripted.)

LD_{Lo}: The lowest recorded dose of a substance reported to cause death in humans or animals exposed for any duration by any route other than inhalation. (The Lo may or may not be subscripted.)

LD_{50}: The lethal dose to 50 percent of a population; the calculated dose of a chemical substance which is expected to cause the death of 50 percent of an entire population of an experimental animal species as determined from exposure to the substance by any route other than inhalation. (The 50 may or may not be subscripted.)

leach: To wash or to drain by percolation; to dissolve minerals by percolating solutions.

leachate: The solution resulting from leaching.

leachate runoff: The loss of solid waste pollutants from land by solution or suspension in a water flow that causes physical removal.

leukemia: A disease in mammals characterized by an abnormal increase in the number of leukocytes in the tissue and/or blood.

leukopenia: An abnormal deficiency of leukocytes in the blood.

Level I chemical analysis: Chemical analysis of effluents designed to determine concentration levels of general categories of pollutants. Used for broad qualitative screening.

Level II chemical analysis: Chemical analysis of effluents designed to determine concentration levels of specific pollutants.

lipid: General term applied to tissue extracts that are soluble in a mixture of chloroform and methanol, including oils, fats, and waxes of animal or vegetable origin; important polar lipids include glycerides, long chain fatty acids, sterols, and certain vitamins.

m-isomer: See meta isomer.

magnification (biological): The ability to accumulate amounts of substances in concentrations greater than those found in the nutritive environment, especially among the higher carnivores of a food chain.

MATE: See Minimum Acute Toxicity Effluent

$MATE_{AC}$ (expressed in $\mu g/m^3$): $MATE_{air,\ carcinogenicity}$. The estimated concentration of a contaminant in air which will not result in carcinogenic effects in exposed humans, provided exposure is of limited duration; applicable to emission streams to the atmosphere.

$MATE_{AC1}$ (expressed in $\mu g/m^3$): The $MATE_{AC}$ based on a model that equates the $MATE_{AC}$ for a substance with its TLV or NIOSH recommendation (for workroom air concentration) which takes into consideration the potential carcinogenicity of the substance.
$MATE_{AC1} = 10^3 \times$ TLV or NIOSH recommendation ($\mu g/m^3$).

$MATE_{AC2}$ (expressed in $\mu g/m^3$): The $MATE_{AC}$ based on a model incorporating the adjusted ordering number that reflects carcinogenic potential.
$MATE_{AC2} = 7 \times 10^4$/adj. ord. number.

$MATE_{AE}$ (expressed in $\mu g/m^3$): $MATE_{air,\ ecology}$. The estimated concentration of a contaminant in air which will not adversely affect the ecology (especially vegetation) provided exposure is of limited duration; applicable to emission streams to the atmosphere $MATE_{AE}$ = lowest concentration (corrected to 24-hour exposure reported to produce effects in vegetation (in $\mu g/m^3$).

$MATE_{AH}$ (expressed in $\mu g/m^3$): $MATE_{air,\ health}$. The estimated concentration of a contaminant in air which will not result in adverse effects to human health provided exposure is of limited duration; applicable to emission streams to the atmosphere.

$MATE_{AH1}$ (expressed in $\mu g/m^3$): The $MATE_{AH}$ based on a model that equates either the TLV or the NIOSH recommendation for workroom air concentration for a chemical substance with its $MATE_{AH}$ (for substances other than recognized carcinogens).
$MATE_{AH1} = 10^3 \times$ TLV or NIOSH recommendations (mg/m^3)

$MATE_{AH1a}$ (expressed in ppm): Same as $MATE_{AH1}$ expressed in ppm.

$MATE_{AH2}$ (expressed in $\mu g/m^3$): The $MATE_{AH}$ derived from a model which utilizes the LD_{50}, oral, rat (or most closely related value) and incorporates the relationship between TLV_{Lo} and LD_{50} described by Handy and Schindler; the MATE is equivalent to 100 times the TLV_{Lo}.
$MATE_{AH2} = 45 \times LD_{50}(mg/kg)$.

$MATE_{AH3}$ (expressed in $\mu g/m^3$): The $MATE_{AH}$ based on a model which equates $0.1 \times LC_{50}$, LC_{Lo}, or TC_{Lo} with $MATE_{AH}$.
$MATE_{AH3} = 100 \times LC_{Lo}$, or TC_{Lo} (mg/m^3).

$MATE_{AHS}$ (expressed in $\mu g/m^3$): $MATE_{air,\ health,\ standard}$. The $MATE_{AH}$ which reflects the emission concentration for a specific substance as prescribed by an existing Federal regulation which considers human exposure to the emission. $MATE_{AHS}$ = emission level established in Federal regulation ($\mu g/m^3$).

$MATE_{AT}$ (expressed in $\mu g/m^3$): $MATE_{air,\ teratogenicity}$. The estimated concentration of a contaminant in air which will not result in teratogenic effects in exposed humans provided the exposure is of limited duration; applicable to emission streams to the atmosphere. The concentration is derived from a model incorporating the adjusted ordering number that reflects teratogenic potential.

$MATE_{AT} = 7 \times 10^4$/adj. ord. number.

$MATE_{LE}$ (expressed in $\mu g/g$): $MATE_{land,\ ecology}$. The estimated concentration of a contaminant in solid waste (to be disposed as land or into water or land) which will not adversely affect the ecology as a result of direct or indirect exposure of limited duration.

$MATE_{LE1}$ (expressed in $\mu g/g$): The $MATE_{LH}$ derived from a leachate model. It is assumed: (1) that a contaminant in one kg of solid waste may be leached by two liters of water; and (2) that the resulting concentration in the water should not exceed the $MATE_{WE}$.

$MATE_{LE1} = 0.002 \times MATE_{WE}$ ($\mu g/\ell$).

$MATE_{LH}$ (expressed in $\mu g/g$): $MATE_{land,health}$. The estimated concentration of a contaminant in solid waste (whether disposed as land or into water or land) which will not adversely affect human health as a result of direct or indirect exposure of limited duration.

$MATE_{LH1}$ (expressed in $\mu g/g$): The $MATE_{LH}$ derived from a leachate model. It is assumed (1) that a contaminant in one kg of solid waste may be leached by two liters of water; and (2) that the resulting concentration in the water should not exceed the $MATE_{WH}$.

$MATE_{LH1} = 0.002 \times MATE_{WH}$ ($\mu g/\ell$).

$MATE_{WE}$ (expressed in $\mu g/\ell$): $MATE_{water,\ ecology}$. The estimated concentration of a contaminant in water which will not adversely affect the ecology (aquatic life) provided exposure is of limited duration; applicable to effluent streams terminating in surface waters.

MATE_{WE1} (expressed in $\mu g/\ell$): The MATE_{WE} based on a model which equates 0.1 × the LC_{50} or TLm (96 hours test duration, if available) for the most sensitive species with MATE_{WE}.

$\text{MATE}_{\text{WE1}} = 100 \times LC_{50}$ or TLm (mg/ℓ).

MATE_{WES} (expressed in $\mu g/\ell$): $\text{MATE}_{\text{water, ecology, standard}}$. The MATE_{WE} derived from a model relating existing Federal water criteria (established to protect aquatic life) to MATE_{WE}.

$\text{MATE}_{\text{WES}} = 5 \times$ most stringent criteria for water (based on aquatic life effects ($\mu g/\ell$).

MATE_{WH} (expressed in $\mu g/\ell$): $\text{MATE}_{\text{water, health}}$. The estimated concentration of a contaminant in water which will not adversely affect human health provided exposure is of limited duration; applicable to effluent streams terminating in surface waters.

MATE_{WH1} (expressed in $\mu g/\ell$): The MATE_{WH} based on a model relating MATE_{WH} and MATE_{AH}. The model equates the MATE_{WH} to the concentration resulting if the entire contaminant loading from 30 m^3 of air containing the MATE_{AH} concentration is present in 2 liters of water.

$\text{MATE}_{\text{WH1}} = 15 \times \text{MATE}_{\text{AH}} (\mu g/m^3)$.

MATE_{WHS} (expressed in $\mu g/\ell$): $\text{MATE}_{\text{water, health, standard}}$. The MATE_{WH} derived from a model relating existing Federal drinking water standards or criteria to MATE_{WH}.

$\text{MATE}_{\text{WHS}} = 5 \times$ lowest standards on criteria for water (based on public health effects) ($\mu g/\ell$).

MEG: See Multimedia Environmental Goals

metabolite: A product of, or a substance essential to metabolism; often the product of the breakdown of a more complicated substance as part of the metabolism of a living system.

meta isomer: An isomer of a specific organic compound whose molecule includes a benzene ring where substitution has occurred at the 1,3 positions of the ring structure.

methemoglobin: A hemoglobin derivative found in normal blood in small amounts; an oxidized form containing ferric rather than ferrous iron, and thus unable to engage in reversible reactions with molecular oxygen.

methemoglobinemia: The abnormal conversion of unusual amounts of hemoglobin into methemoglobin in the blood, or the resulting presence of abnormal amounts of methemoglobin in the blood.

methemoglobinuria: The presence of methemoglobin in urine.

methylation: To introduce a methyl group; induction of methyl substitution.

Minimum Acute Toxicity Effluents (MATE's): The concentration levels of contaminants in air, water, or solid waste effluents that will not evoke significant harmful responses in exposed humans or the ecology, provided the exposure is of limited duration (less than 8 hours per day).

miscible: Capable of mixing in any ratio without separation of two phases.

mist: Suspended liquid droplets in air generated by condensation from gaseous to liquid state or by physical dispersion (by splashing, foaming, atomizing, etc.).

mucous membrane: A protective membrane rich in mucous glands which lines body passages and cavities that communicate directly or indirectly with the exterior (e.g. the nasal cavity).

multimedia: Air, water, and land as recipients of environmental pollutants, or gaseous, liquid, or solid waste pollutants when used in the context of pollution control levels.

Multimedia Environmental Goals (MEG's): Levels of significant contaminants or degradents (in ambient air, water, or land or in emissions or effluents conveyed to the ambient media) that are judged to be (1) appropriate for preventing certain negative effects in the surrounding populations or ecosystems, or (2) representative of the control limits achievable through technology.

mutagenic: Resulting in a permanent change in hereditary material involving a physical change in chromosome relations, a fundamental change in the arrangement of genes, or an alteration in the makeup of DNA.

narcosis: A state of stupor, unconsciousness, or arrested activity.

natural background: The normal and usual environment, especially its normally occurring condition; in the present context, the normal level of a substance in a particular environment.

necrosis: Localized death of living tissue.

neoplasm (neoplastic): A tumor, whether benign, potentially malignant, or malignant.

neurological: Relating to the nervous system.

NIOSH: National Institute for Occupational Safety and Health.

nonpersistent toxicant: A pollutant with a biological half-life of less than four days.

NSPS: New Source Performance Standards.

nucleophilic: Having an affinity for atomic nuclei, hence electron-donating.

nutrient solution: A water solution of minerals and their salts necessary for plant growth used in lieu of soil with the plants supported by mechanical means.

o-isomer: See ortho isomer.

odor detection level/odor recognition level/odor threshold level: Those levels which relate the concentration of a substance at which a panel of persons in an experiment become aware of the substance's presence.

oncogenic: Producing tumors.

oncology: The study of tumors.

organic: Relating to carbon compounds in which hydrogen is attached to the carbon (the hydrogen may be substituted by other moieties such as halogens).

Organometal: An organic compound in which a metal or metalloid is bonded directly to carbon.

ortho isomer: An isomer of a specific organic compound whose molecule includes a benzene ring where substitution has occurred at the 1,2 positions of the ring structure.

oxidation: The changing of a compound by increasing the proportion of the electronegative part, or the changing of an element or ion by removing one or more electrons, resulting in an increased positive valence.

oxygen transport ability: The capability of red blood cells to transport oxygen.

p-isomer: See para isomer.

para isomer: An isomer of a specific organic compound whose molecule includes a benzene ring where substitution has occurred at the 1,4 positions of the ring structure.

particulates: Minute, separate solid particles of variable composition suspended in air; types include aerosols, dusts, fumes, mists, and smoke.

Particulate Polycyclic Aromatic Hydrocarbons (PPAH): The occurrence of polycyclic organics in association with particulate matter.

peritoneal cavity (peritoneum): The abdominal cavity, as defined by its protective lining, the peritoneum.

phage: Viruses which invade and destroy bacteria and similar organisms.

pharyngitis: Inflammation of the pharynx.

photochemical activity: The action of radiant energy upon chemical substances, inducing chemical change.

photochemical reaction kinetics: The rate of a photochemical reaction.

photolysis: Chemical decomposition by the action of radiant energy.

photooxidation: Oxidation as a result of the influence of radiant energy.

photosensitive: Sensitive or sensitized to the effect of radiant energy.

phytoplankton: Passively floating minute plant life in a body of water.

phytotoxicity: Toxicity to plant life.

pneumoconiosis (pneumonitis): A chronic lung disease caused by physical irritation.

polar(ity): Referring to a molecule having unequal charge distribution.

polycyclic (compounds): Compounds whose molecular structure includes two or more fused rings.

polymer: A chemical compound with repeating structural units resulting from the combination of the repeating molecules.

PPAH: See Particulate Polycyclic Aromatic Hydrocarbons

precursor: A substance from which another substance is formed.

promoter: A substance that increases the biological activity of another substance.

protein: A macromolecule formed by a sequence of amino acids involving peptide bonds (-CO-NH-) in which the carbonyl part (-CO-) comes from the carboxylic group of one of the amino acids and the imino group -NH- from the amino group of another amino acid.

protoplasm: The organized colloidal complex of organic and inorganic substances that constitutes all living parts of cells.

psychosis: A fundamental metal derangement characterized by defective or lost contact with reality.

pulmonary: Relating to the lungs.

pyrolysis: Decomposition of organic substances by heat.

rem: Abbreviation of "roentgen equivalent man"; the calculated dose (equivalent) derived from dosage in rads ($\frac{\text{energy of radiation}}{\text{mass of tissue}}$) and other modifying factors such as the relative biological damage produced by the radiation and the distribution of radiation.

renal: Of or relating to the kidneys.

rural: Geographic areas usually devoid of a concentrated human population and its influences, e.g. areas more than 200 miles from urban centers.

sarcoma: A malignant cancerous tumor involving bone, connective tissue, or striated muscle.

secondary pollutant associations: Those reactions and interactions among substances emitted in mixtures after they enter the receiving medium.

silicosis: A lung disease resulting from inhalation of silica dusts, marked by massive fibrosis and shortness of breath.

simple asphyxiant: A compound which does not produce physiologic effects except when it is present to the extent of limiting available oxygen concentration.

somatic cell division: Reproduction or regenerative cellular division (mitosis) in body tissue other than gametes.

stack dispersion: The diffusion or scattering of pollutants or source emissions into the air (literally, from smoke stacks).

stack flow: The rate at which source effluents are released into the air (from smoke stacks).

STP: Standard Temperature and Pressure, i.e., 0°C, 1 atmosphere.

subcutaneous: Under the skin.

sublethal: A harmful effect that does not result in death.

sublime: To pass or cause to pass directly from solid state to vapor state.

surfactant: A surface-active substance, i.e., an agent that alters (usually reduces) the surface tension of water.

synergism: The ability of a substance to achieve or cause an appreciably different or greater effect than its own usual effect when present in conjunction with another substance.

systemic: Relating to an entire life system as a unit.

tainting levels: Levels of contaminants in water which cause objectionable taste, odor, or color in exposed aquatic species.

TC_{Lo}: The lowest concentration of a substance in air reported to cause carcinogenic, teratogenic, or other toxic effects in humans or animals.

TD_{Lo}: The lowest dose reported to induce carcinogenic, teratogenic, or other toxic effects in humans or animals when introduced by any route other than inhalation.

teratogenic: Inducing structural and/or functional deviation in an embryo during its development, resulting in congenital birth defects.

thermal dehydrogenation: The removal of hydrogen by the action of heat.

threshold level: The level of exposure concentration or dosage of a toxicant exposure below which no effects are expected to occur.

Threshold Limit Value (TLV): Levels of contaminants considered safe for workroom atmosphere, as established by the American Conference of Governmental Industrial Hygienists (ACGIH). Ten hours per day or 40 hours per week exposure is assumed.

TLm, TL_{50}: Tolerance Limit median (often used interchangably with aquatic LC_{50}): the concentration of a substance in water which will cause the death of 50 percent of an experimental aquatic animal population under controlled conditions and time of exposure (most often 96 hours).

TLV: See Threshold Limit Value.

TLV_{Low}: A value (introduced by Handy and Schindler) relating TLV's to LD_{50}'s described by the equation: $(TLV)_{low} = 4.5 \times 10^{-4} (LD_{50})$

TLV_{SA}: The threshold limit value for a simple asphyxiant generated by the MEG's methodology.

TOC: See Total Organic Carbon.

Total Organic Carbon (TOC): A test method for water; expresses the total amount of organic carbon.

toxic encephalopathy: Brain disease involving alterations of brain structure induced by toxic effects.

toxocity: The ability of a chemical molecule or compound to produce injury once it reaches a susceptible site in or on the body.

toxicology: The study of the actions, detections, and treatment of poison and poisonings.

trachea: The main trunk of the system of tubes by which air passes to and from the lungs in vertebrates.

tracheitis: Inflammation of the trachea.

tumor: A growth arising from pre-existing tissue without normal or obvious cause, independent of normal cellular growth, having no positive physiological function.

ubiquitous: Existing or encountered everwhere at the same time.

urban: Within the limits or influences of areas of dense human population, including cities, their suburbs, and nearby towns (within 75 miles) or areas within the direct air flow of influenced areas.

vapors: The gaseous form of substances that are liquid or solid under standard conditions; can be returned to normal state by either increasing pressure or decreasing temperature; will diffuse.

vapor pressure: The pressure exerted by a vapor that is in equilibrium with its solid or liquid form.

vasoconstriction: A narrowing of the lumen (cavity radius) of a blood vessel.

viscosity: The resistance of liquids, semisolids, and gases to movement.

viruses: Submicroscopic entities capable of being introduced into specific living cells and of reproducing inside such cells.

water dispersion: The diffusion or scattering of pollutants or source emissions into or through water from higher concentrations to lesser concentrations.

Wiswesser Line-Formula Notation (WLN): A notation which is unique and unambiguous for each organic chemical compound, in which symbols are arranged according to a fixed procedure into a word-like sequence that describes exactly the composition and structure of the compound; provides an important tool for indexing.

WLN: See Wiswesser Line-Formula Notation

worst case: A term applied to pollution situations in which all negative parameters affecting an emission or its reception are maximized.

Zero Threshold Pollutant: A term commonly used to denote those compounds for which a threshold has not been established; especially referring to genotoxins.